ETREL

ELECTRIC VEHICLE CHARGING STATION

ETREL INCH

SMART CHARGING FEATURES

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CHARGING STATION

Etrel INCH charging station supports many functionalities that can help with overload prevention, frequency regulation, power management of one charger or power management of a cluster of chargers.

Figure 1: Etrel INCH charging station

All OCPP 1.6 SOAP is fully supported and all messages and methods of OCPP 1.6 JSON are also supported. The full support of OCPP 2.0 JSON is upcoming.

In addition, special algorithms were developed to optimize the charging process. Main scopes of algorithms of smart charging solutions:

- Overload prevention

- Frequency regulation

- Charging process optimization

    o Economic/Price optimization of charging

    o Operation optimization

- Power management

    o Cluster management

Each scope consists of several smart charging features, and new ones are being added routinely with normal charging station updates.

ADDITIONAL MEASUREMENTS

The charging station can operate on its own, however, it can be beneficial to use additional data at the location where possible. For example, data of household consumption and data of possible production of energy at the location, can be measured and transmitted to the charging device where the data is evaluated, analysed and used in algorithms. One possibility for this is the collection of data with the use of Etrel Load Guard. Additional measurements enable better operation of smart charging.

Figure 2: Etrel Load Guard

BACK OFFICE (SOFTWARE SOLUTIONS)

Additional option is the use of charging monitoring system, for example Etrel Ocean, which enables additional smart charging features and better operation of existent. With monitoring system, the overview and control of larger number of charging stations becomes simple. The major benefits, that are supported with the use of Etrel Ocean are:

- Power management
    - Cluster management
    - Demand response activation
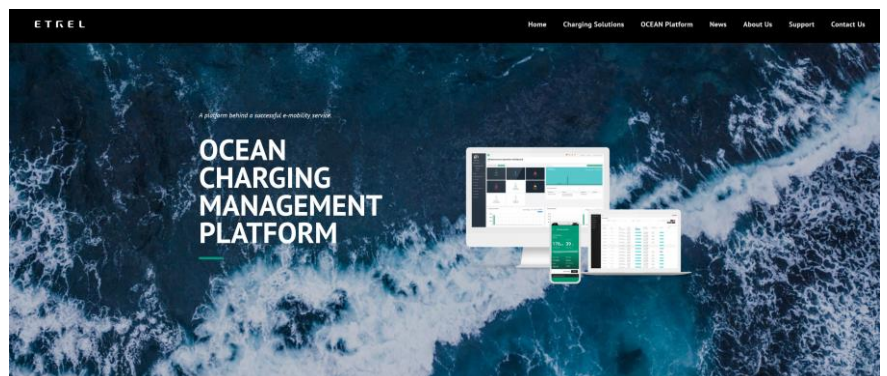   - Load area power management

Figure 3: Etrel Ocean

2 | SMART CHARGING SOLUTIONS AT THE LOCATION

OVERLOAD PREVENTION

Main functionality of the overload prevention algorithm is to decrease the EV charging load to prevent the overload of grid connection point. This function has the highest priority among all the power management algorithms. The EV charging load shall be controlled so that the total load (household load + charging load) of grid connection point is below the rated current of the main fuse.

When the user connects EV to charger, and prior to beginning of charging, the charger determines the current available for charging as the difference between the rated current of main fuse (reduced by a safety margin that can be pre-set by the user via charger's web interface) and the last measurement received from Load guard.
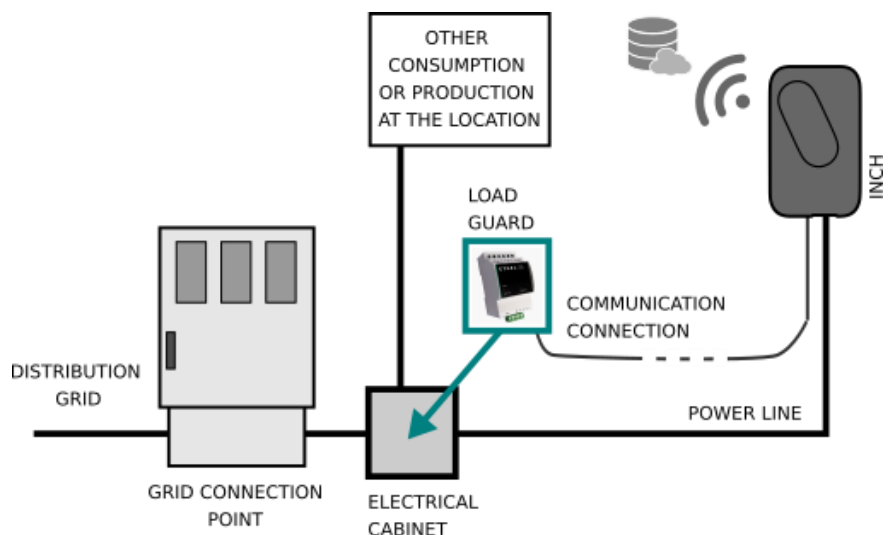

Figure 4: Use of household consumption data to prevent overload

By using Load Guard device, the household load can be measured and used in overload prevention algorithms:

- Static limit of maximum allowed charging current per phase.

- Static limit of maximum allowed charging current per phase in case connection with Load Guard sensor / back-end is lost.

- Detection and visualisation of available supply and automatic adjustment of charging power.

- Detection and visualisation of surplus energy returned to the grid (Production from renewable energy sources).

FREQUENCY REGULATION

Frequency regulation can prevent grid breakdowns. Frequency depends on the balance of production and consumption in the electricity grid. When the consumption is bigger than production frequency falls below 50 Hz. In the event when the production is bigger than the consumption frequency can raise above the 50 Hz.

To bring the frequency back to the optimal 50 Hz either the consumption or production needs to be changed. With charging stations, it is very easy to manage the load and with this, the frequency of the grid.

Frequency regulation works on a charging station level. Each charging station measures the frequency value 3 times per seconds and based on the measured frequency automatically reacts by lowering the current.

In the case when the frequency is lowered because the consumption is too high, the charging station can simply decrease the charging power (currents). Regulation of the charging current is made on basis of the frequency limit settings. If the system frequency is lower than nominal 50 Hz, the charging current will also be lowered.

In the table below, the example of settings how much the charging current changes is based on the frequency value and how long it must persist on a particular current is based on hysteresis used. RND in a table stands for random, since you don't want that all the chargers would stop with regulation at the same time after the grid event.

This is just the example and settings can be configured directly on each charger as required at the location.

Frequency limit [Hz]	Hysteresis start [s]	Hysteresis stop [s]	Output current [A]
49.5	1	5 * RND()	32
49.0	2	10* RND()	25
48.5	2	50* RND()	15
48.0	2	500* RND()	6
47.5	2	1200* RND()	0

CHARGING PROCESS OPTIMIZATION

ECONOMIC/PRICE OPTIMIZATION OF CHARGING

When different energy tariffs are set, the charging station can optimize the charging process to ensure that the price of charging will be the lowest possible. Based on the set parameters, the charging algorithm calculates the optimal charging schedule plan.

For example, normally, the charging during the night would have the lowest price, however the exact time interval of low tariffs could influence the calculation.

The possible production of energy at the location could be treated as being of high tariff, or the use of this energy for charging would be preferred and designated with low tariff. In most cases of public charging stations, the user wants the electric vehicle to be charged as soon as possible and the price optimization of charging is not desired.

The calculation of optimal charging plan:

- Based on energy tariffs.

- Time scheduling of charging towards lower tariffs or self-consumption when user preferences and pricing allows it.

- Evaluation of on-site production (e.g., photovoltaics).

OPERATION OPTIMIZATION

In some cases, the easiness of the charging process can be supported with the use of machine learning and pattern recognition to evaluate the user habits and offer the charging schedule plan, optimized to specific user (by evaluation of the historic data of charging).

With the setting of user's departure time, the charging process could optimize the charging of a whole cluster. The electricity price can be a part of optimization algorithms, or not. In case of public charging stations, the operation optimization is usually not wanted, however its main use are semi-public charging stations (charging at workplace) and individual users.

To achieve better operation with existent devices, to connect to other systems, or to configure additional functionalities, the digital inputs and outputs can be used.

The communication protocol is Modbus. The support for Modbus protocol further extends the options for integration with external systems and means of monitoring and control of operation of individual charging station or a cluster. It can be implemented for control of operation on local level, or for the remote control from the back-end office.

Operation optimization is linked to other functionalities, e.g. price optimization and power management possibilities and is dependent on the exact use case scenario.

Different configurations are possible, using only charging stations to manage the whole cluster, using the Etrel Ocean monitoring system, or external monitoring system.

Because of it, the optimization of the complete system is subjected to the use case of individual customer and is not limited only to:

- Machine learning and pattern recognition using built-in AI to predict and optimise each charging session.

- Collection of user's departure time over app or touch screen to refine automatically suggested charging profile.

- Support for Modbus protocol for integration with external smart building systems.

POWER MANAGEMENT

Basic power management is performed on individual charging station and consist of several settings and is supported by other functionalities. It can also be performed on the level of back end for load areas, sub load areas, or individual charging stations.

CLUSTER MANAGEMENT

The goal of this functionality is to distribute the power available for charging among several chargers in the cluster when multiple EVs are charging. Cluster management on level of charging station is using one charging station designated as master of the cluster.

- Based on user preferences and current installation's load conditions.

- Master-slave relationship with floating master. Connection of up to 16 chargers possible.

The total consumption of the cluster can be limited with the maximal capacity of the grid connection point. To optimize this functionality, user charging preferences and EV onboard charger's characteristics must be known or estimated. User charging preferences can be obtained by the charger when user enters his preferences into the charging station's touch screen, into mobile app or charging station calculates them using the preferences prediction algorithm with the historic charging data.

When several chargers are installed behind the grid connection point the control algorithm must decide how to distribute the current available for charging to individual charging sessions (EVs) where all users' charging preferences must be satisfied all the time. Algorithm must also prevent grid connection point overload if the full charging power of all charging station in cluster would cause overload.

In Master-slave configuration, the connection of up to 16 electric vehicles is possible.

Larger cluster (up to 50 electric vehicles), is possible with use of industrial computer and connection to Etrel Ocean management software.

OPERATION

One of the charging stations is assigned role of a cluster master. Cluster master serves as a main communication channel between all the charge points in the cluster and is responsible for power management algorithms. This allows cluster to do the power management even if the communication with the back office is lost as all the calculations are done within the cluster.

Algorithm determines the current available for charging as a difference between the actual EV charging currents and the required reduction of grid connection point load.

Cluster management algorithm then distributes the current available to individual EVs with consideration of user's charging preferences and EV on board chargers' characteristics:

- Calculation of required current: Charging current needed (per phase) to deliver the required energy till the end of time period available for charging is calculated for each charging session.

- Required currents of all charging sessions are summed (per phase).

- Calculation of current set points for individual EVs: Current available for charging (per phase) is distributed to individual sessions according to the share of their required current in the total of all required currents in the cluster.

A problem arises when EVs with 1- and 3-phase chargers are currently connected to chargers. Calculation of current set points for individual EVs may result in different phase currents for the same EV with a 3-phase charger; Consequently, the currents assigned to individual EVs must be recalculated to reach a symmetrical load of EVs with 3-phase chargers.

For this recalculation the algorithm considers a "fairness factor". A high factor means, that all EVs are considered on an equal basis: the share of EV's set point current in the sum of set point currents of all EVs in the cluster corresponds to the share of EV's required current in the sum of required currents of all EVs in the cluster.

ADDITIONAL OPTIONS

If the cluster is part of a household, multi-dwelling house or if additional loads are connected to the same connection point Load guard unit should be added to the installation. Load guard can measure values of all the loads in the installation and with this data charging station can manage the charging power.

Additional options for cluster management are supported on the level of back-office, with the use of Etrel Ocean monitoring system.

3 | SMART CHARGING SOLUTIONS ON LEVEL OF BACK OFFICE (SOFTWARE SOLUTIONS)

Software solutions represents power management solutions that are done by the back-office software. Etrel Ocean monitoring system can be used. All charging stations that use OCPP 1.6 protocol can be managed by the software.

All the software solutions on level of back office can be used together with the power management functions on the level of charging stations.

Main software power management solutions:

- Cluster management
- Demand response activation
- Load area power management

POWER MANAGEMENT

Basic power management is performed on individual charging station and consist of several settings and is supported by other functionalities. It can also be performed on the level of back end for load areas, sub load areas, or individual charging stations. Limitation in using only software solution is the communication. If the communication between the charger, other charging stations of the cluster and back office fails, new schedules and power management can't be communicated to the charging stations.

Best case scenario is using combination of both options which represents a safe failback to the cluster management on level of charging stations in case of communication loss.

CLUSTER MANAGEMENT

Solution for power management of clusters using software (monitoring system) is very similar to the solution of cluster management enabled on the level of the charger. The main difference is that cluster master is not used, as back office software works as a cluster master and delegates the schedules and charging power values to each charging station that is part of the cluster.

Charging station sends heartbeat signal to the back office every X minutes (heartbeat frequency can be set in the back office settings module), if there is no response message received from the back office charging station immediately goes to the power fallback mode where output current of the charging station is reduced to the minimum value (usually 6 A per phase).

This is done to minimize the possibility of overloading the grid or connection point during the communication failure. If this is not done problems can especially occur when new EVs arrive to charging station during the time with no communication with software back office. If there are other (unmanageable) loads in your cluster, then software solution cannot perform cluster power management.
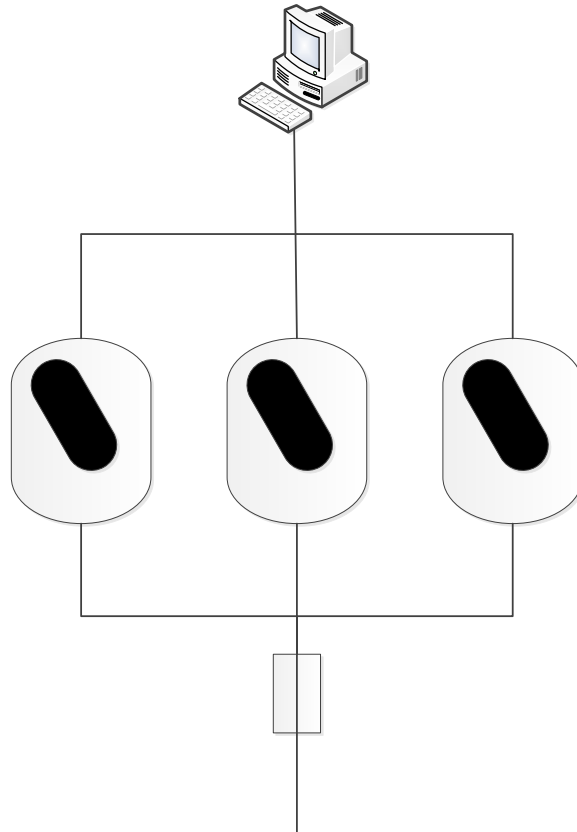

Figure 5: Managing of cluster from back office

Larger cluster (up to 50 electric vehicles), is possible with use of industrial computer and connection to Etrel Ocean management software.

DEMAND RESPONSE ACTIVATION

In some cases, the demand response functionality is needed. Distribution system operator can set the rules, that can be implemented in Etrel Ocean to enable the control of charging stations operation:

- Remote power manipulation by DSO.

- Remote power manipulation by energy supplier.

LOAD AREA POWER MANAGEMENT

Load area power management allows operator to group charging station and clusters into load areas. Software allows operator to manage the power of each load area separately. This gives operator ability to manage

power only in the area where problems occur.

When charging station are grouped into one load area, the whole load area then acts as one charging station. For example, if the operator decreases the charging power of the load area for 50 kW, charging power of all the chargers in the area will reduce for 50 kW, some will reduce more and some less depending on the charging preferences on each individual charging station.

Charging station can be part of multiple load areas. One load area that represents a big part of the electrical grid, can have multiple small sub load areas, where only one or few charging stations can in one of them. Example can be seen on the following figure.
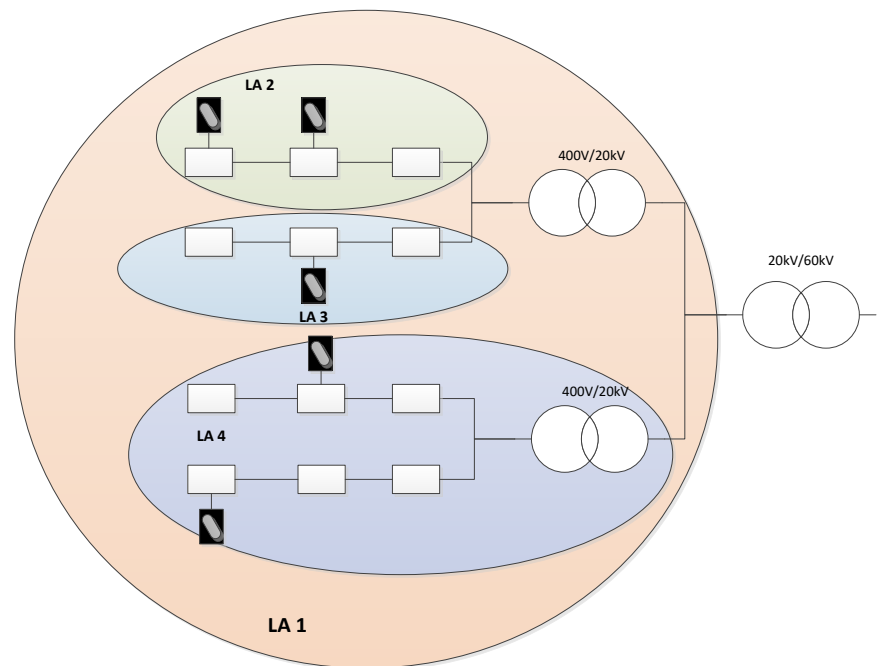

Figure 6: Load area and sub load areas

How load areas and sub load areas are arranged and how the operator then manages power can be set arbitrary. Power can be managed only for the whole load area LA1 of for each sub area (LA 2, LA 3 and LA 4) separately.

Two integration options of such system exist.

In the first option Etrel Ocean gathers all the data from each charging stations separately and aggregates them with the data from charging station from the same load area. This data is then exchanged with the smart grid system which controls the grid (other power plants and consumers).

In the second option, the data from each charging station (grid connection point) is sent to the smart grid system and it is that system responsibility to aggregate data to load areas and sub load areas and to manage power consumption of all load areas.

4 | LIST OF SMART CHARGING FEATURES

Economic/Price Optimization of Charging

On local level or remotely

- Based on energy tariffs.
- Time scheduling of charging towards lower tariffs or self-consumption when user preferences and pricing allows it.
- Evaluation of on-site production (e.g., photovoltaics).

Operation Optimization

On local level or remotely

- Frequency regulation.
- Machine learning and pattern recognition using built-in AI to predict and optimise each charging session.
- Collection of user's departure time over app or touch screen to refine automatically suggested charging profile.
- Support for Modbus protocol for integration with external smart building systems.

Overload Prevention (of Fuse and/or Grid Connection Point)

On local level, with or without using Etrel Load Guard, or with management system, e.g. by using Etrel Ocean:

- Static limit of maximum allowed charging current per phase.
- Static limit of maximum allowed charging current per phase in case connection with Load Guard sensor / back-end is lost.
- Detection and visualisation of available supply and automatic adjustment of charging power.
- Detection and visualisation of surplus energy returned to the grid (Production from renewable energy sources).

Demand Response Activation

With management system, e.g. by using Etrel Ocean

- Remote power manipulation by DSO.
- Remote power manipulation by energy supplier.

Cluster management

On local level or with management system, e.g. by using Etrel Ocean

- Based on user preferences and current installation's load conditions.
- Master-slave relationship with floating master. Connection of up to 16 chargers possible.
- Load area power management.
- OCPP 1.6 fully supported, OCPP 2.0 in the road map, will be fully supported soon. Other OCPP nonstandard messages are also supported (related with building consumption or cluster consumption).

5 | CONTACT INFORMATION

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