EV Battery Charging Stations

CONTENTS

Renewable Energy and e-Mobility

EV deployment requires four concurrent strategies:

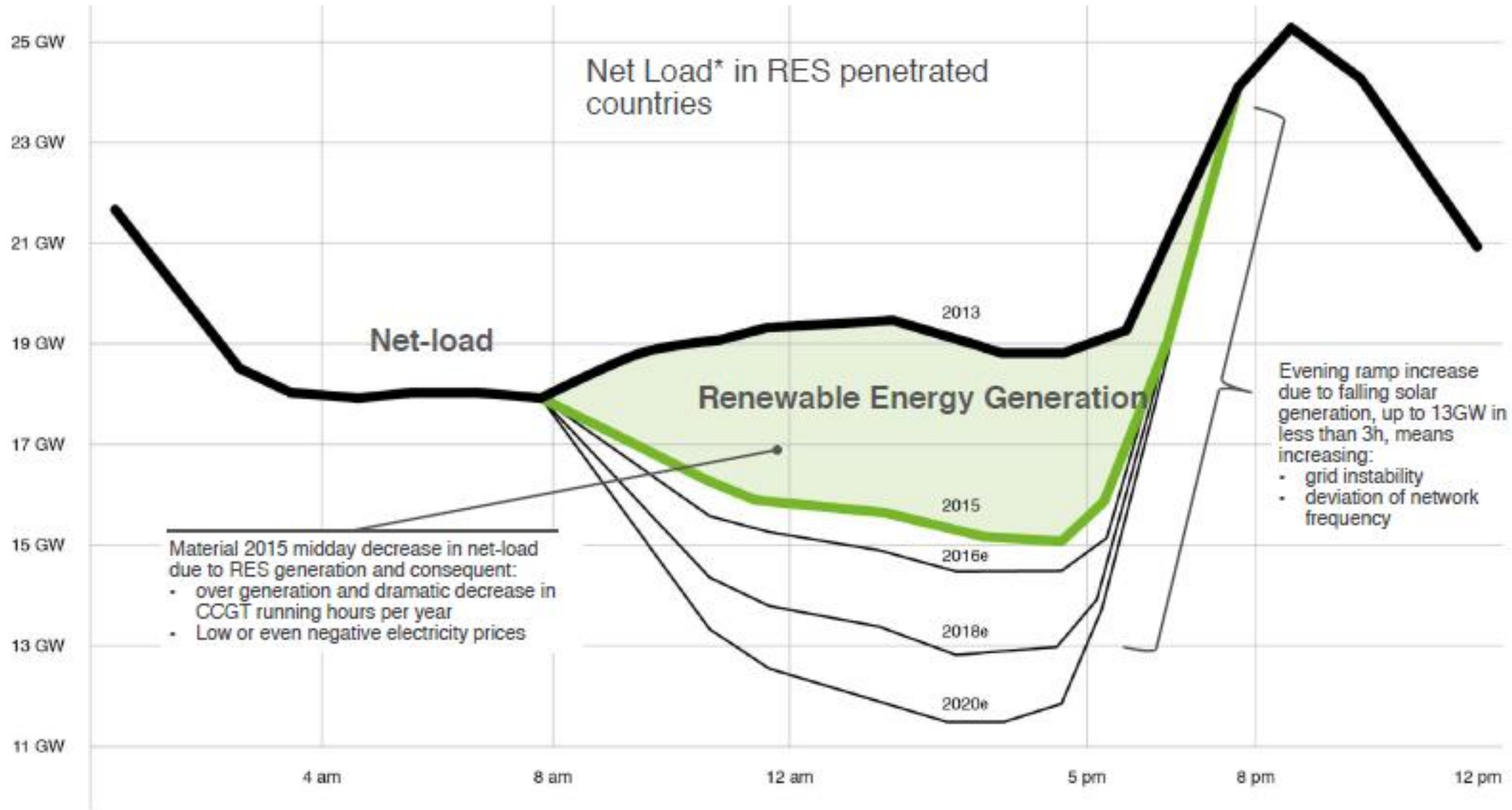
- ***electrification*** *of vehicles;*
- *provision of sufficient* ***charging equipment****;*
- ***decarbonisation*** *of the electricity generation;*
- ***integration*** *of electric vehicles into the grid.*

EV deployment growth would allow a ***higher share of variable renewable energy*** *(VRE) in the power system, via five* ***areas of interaction****:*

- *actively using the mobile battery storage system in the vehicle* ***(V2G);***
- *use of second-hand batteries in a* ***"second life"*** *role as stationary battery storage systems* ***(SLB);***
- *widespread deployment of* ***charging infrastructure****;*
- *evolution in the charging* ***behaviour of EV owners****;*
- *provision of other* ***ancillary services from EVs*** *to the grid, such as frequency regulation, shaving peak demand, power support to enhance operation, and reserve capacity to secure the grid by stored energy in its batteries.*

Renewable Penetration – Duck Curve

Renewables penetrated countries need Grid Support



* **Net Load** means the difference between the forecasted load and expected electricity production from RES. The Graph shows the net-load in a typical March day in California

Impact of e-mobility on the electricity grid in Italy

In presence of **10 million PEVs** (Plug-in Electrical Vehicle)
Energy consumption about 2.5MWh / year x 10 ^ 7 = **25 TWh / year** -> sustainable
Power absorbed in simultaneous slow charge **P = 60GW** -> too high, not sustainable
Energy storage system capacity distributed on the PEV: E = 200 GWh

Calculation hypothesis
Mileage 12.500km / year x 0.2kWh / km = 2.5MWh / year
Battery capacity of a PEV = 20kWh (expected to grow, 40kWh is more realistic in near future)
Charging power 6kW corresponds to a speed (C rate) of 0.3C
On average, vehicles are parked in an idle state for more than 90% of the time

Risk of congestion in the distribution network even with fewer PEVs

Solutions: V1G and V2G

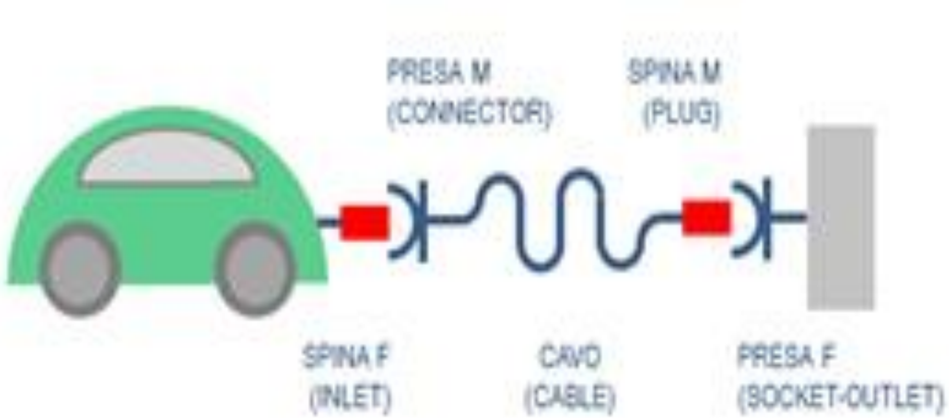
Smart Charging (V1G)

- Unidirectional power flow (Forward), battery charger only
- Vary the charging power to optimize infrastructure and network operation
- Rates according to the charging time, to discourage peak evening hours
- Allows the user of the PEV to save on charging costs

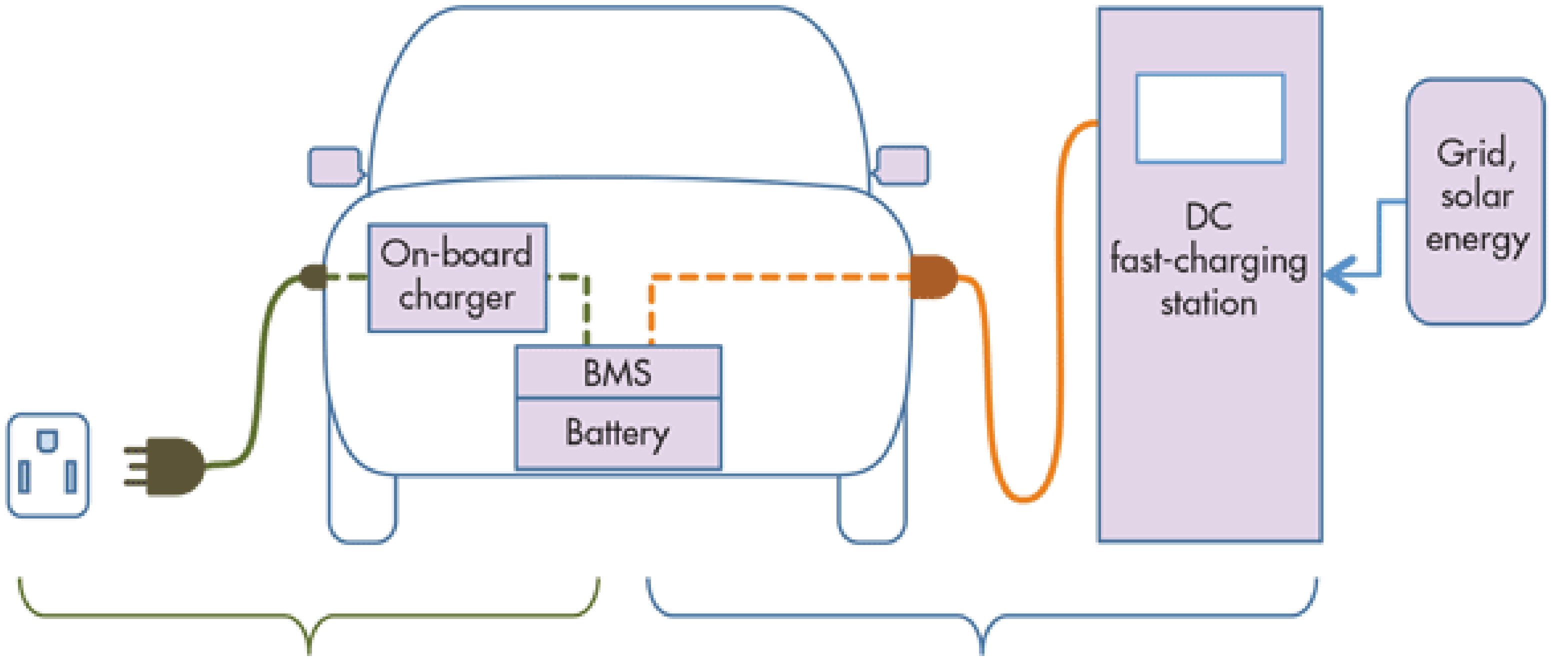
Vehicle to Grid (V2G)

- Bidirectional power flow (also Reverse), battery charging and discharging
- Provision of "ancillary" network services to the TSO, remunerated
- Frequency Adjustment, Voltage Support
- PEVs must be coordinated by an Aggregator, or Balance Service Provider

BEV – Connection to Charging Station



EVSE – AC and DC Charging



AC charging

- Every vehicle has an on-board charger.
- Limited power, slow charging.

DC charging

- Infrastructure investment is shared among hundreds of users.
- Large power rating, fast charging.
- Capable of integration with renewable resources.

EV – Charging Modes

Charging mode	Mode 1	Mode 2	Mode 3	Mode 4
Current	AC	AC	AC	DC
Power	3-7 kW	3-7 kW	3-22 kW	> 22 kW
Battery Charger	On board	On board	On board	Off board
Charging time	6-8 h	4-8 h	4-8 h (slow) 1-2 h (quick)	20-30 min (fast)
Location	Private	Private	Public	Public
Protection & Communication	None	Only protection, in the cable	Both in charging station	Both in charging station
Vehicle plug / charging plug	Type 1 or 2 Domestic plug	Type 1 or 2 Domestic/Industrial	Type 2	CCS Combo or CHAdeMO

EV – Charging Modes

Mode 1: Slow charging from a standard socket, like the domestic one.

Current and voltage are respectively limited to 16A and 250V single-phase.

It corresponds to a recharge at home, simply by plugging the cable to any socket.

EV – Charging Modes

Mode 2: Slow charging from a standard socket (both **domestic** and **industrial socket).**

Cable is provided with a Control Box, providing protective functions to ensure safety of charging process.

Typically installed on portable chargers for electric vehicles.

Current limit is set up to 32A.

Voltage limit at 250 V in single-phase and 480 V in three-phase.

This mode in Italy is allowed (like Mode 1) only for private charging while it is prohibited in public areas.

EV – Charging Modes

Mode 3: Slow or quick charging using an EV multi-pin socket with both control and protective functions.

This mode requires that the vehicle is charged through a power supply system permanently connected to the electrical network. The Control Box is integrated directly into the dedicated charging point (also defined EVSE, Electric Vehicle Supply Equipment, according to IEC standards).
Charging stations operating in mode 3 allow charging up to 32 A and 250 V in single-phase and up to 32 A - 480 V in three-phase.

Mode 3 is implemented in **wallboxes**, **public charging points** and **automatic charging systems** in **AC**.

EV – Charging Modes

Mode 4: Fast charging, with control and protective functions, an off-board charger and a special connector type.

The DC supply limits are set up to 400 A and 1000 VDC, depending on the connector technology.

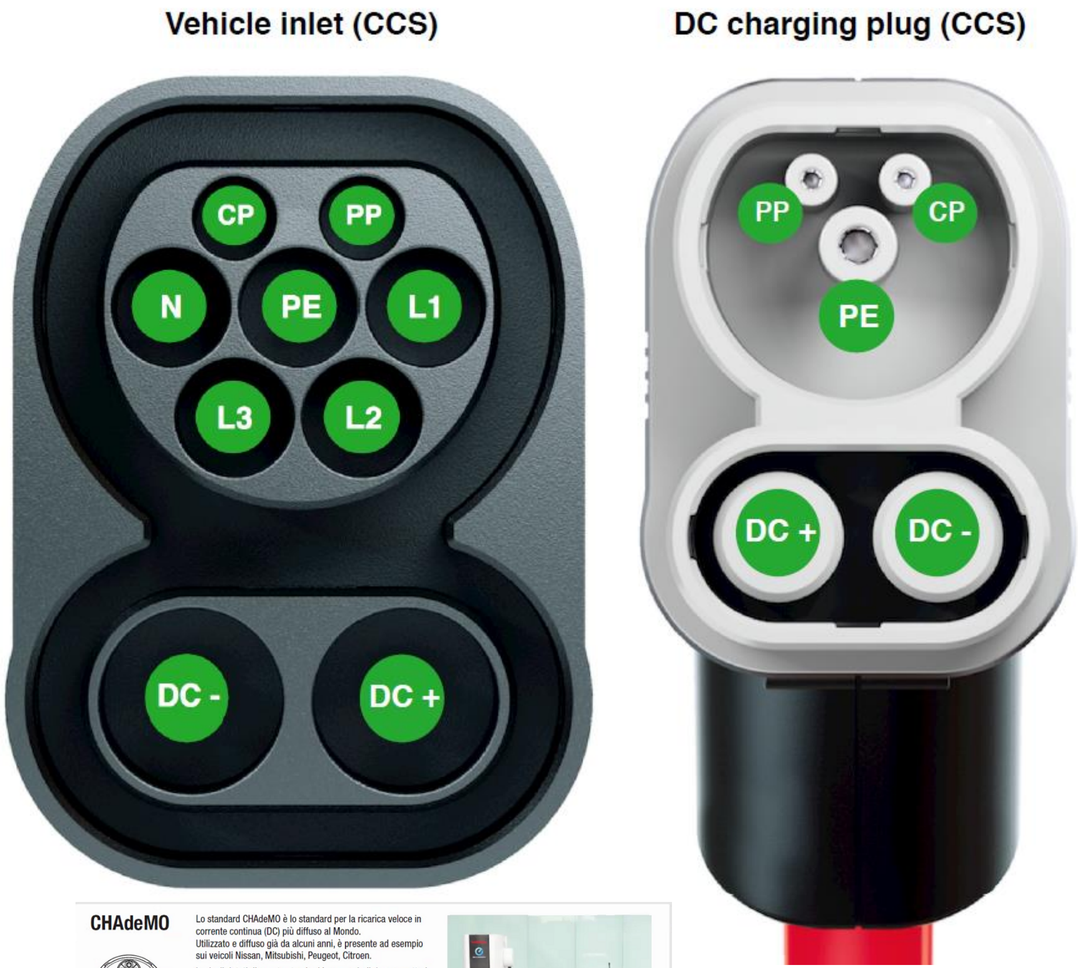
EV is connected to grid through an EVSE, as a public DC fast charging station.

Two standards exist, one Japanese and one European called respectively CHAdeMO and CCS Combo.

Connectors – EV Charging

	Type 1/USA	**Type 2**/Europa	**GB**/China
Alternating current (AC)	 SAE J1772/IEC 62196-2	 IEC 62196-2	 GB Part 2
Direct current (DC)	 IEC 62196-3	 IEC 62196-3	 GB Part 3/IEC 62196-3
„Combined AC/DC charging system“	 SAE J1772/IEC 62196-3	 IEC 62196-3	

Connectors – EV Charging



CONTROL PILOT
It carries an electrical signal sourced by EVSE. Control pilot is the primary control conductor and is connected to the equipment ground through control circuitry on the vehicle. It serves as medium for Power-Line-Communication (PLC)

PROXIMITY PILOT
The PP pin transmits a signal which allows the EV to detect when it is plugged in.

PROTECTIVE EARTH
PE is an equipment grounding conductor

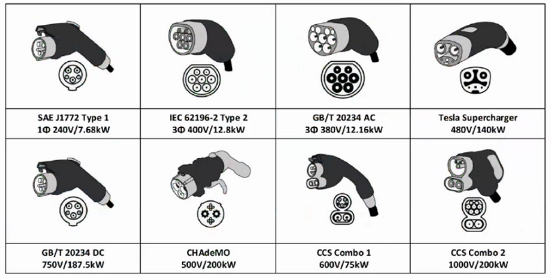


Figure 5. Global male and female battery charger connectors (Ronanki et al., 2019).

IEC 61851 – safety related standard for EV charging

CONTROL PILOT

It is an electrical signal that is sourced by the EVSE. Control pilot is the primary control conductor and is connected to the equipment ground through control circuitry on the vehicle and performs the following functions:

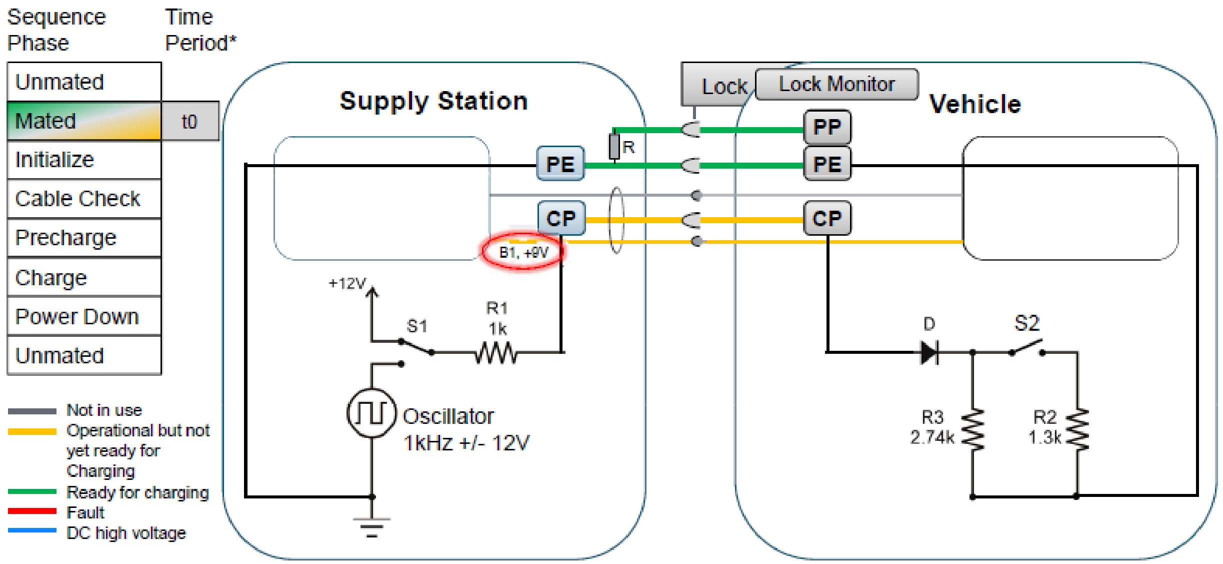
- Verifies that the vehicle is present and connected
- Permits energization/de-energization of the supply
- Transmits supply equipment current rating to the vehicle
- Monitors the presence of the equipment ground
- Establishes vehicle ventilation requirements
- Serves as medium for Power-Line-Communication (PLC)

PROXIMITY PILOT

The PP pin transmits a signal which allows the EV to detect when it is plugged in.

PROTECTIVE EARTH

PE is an equipment grounding conductor

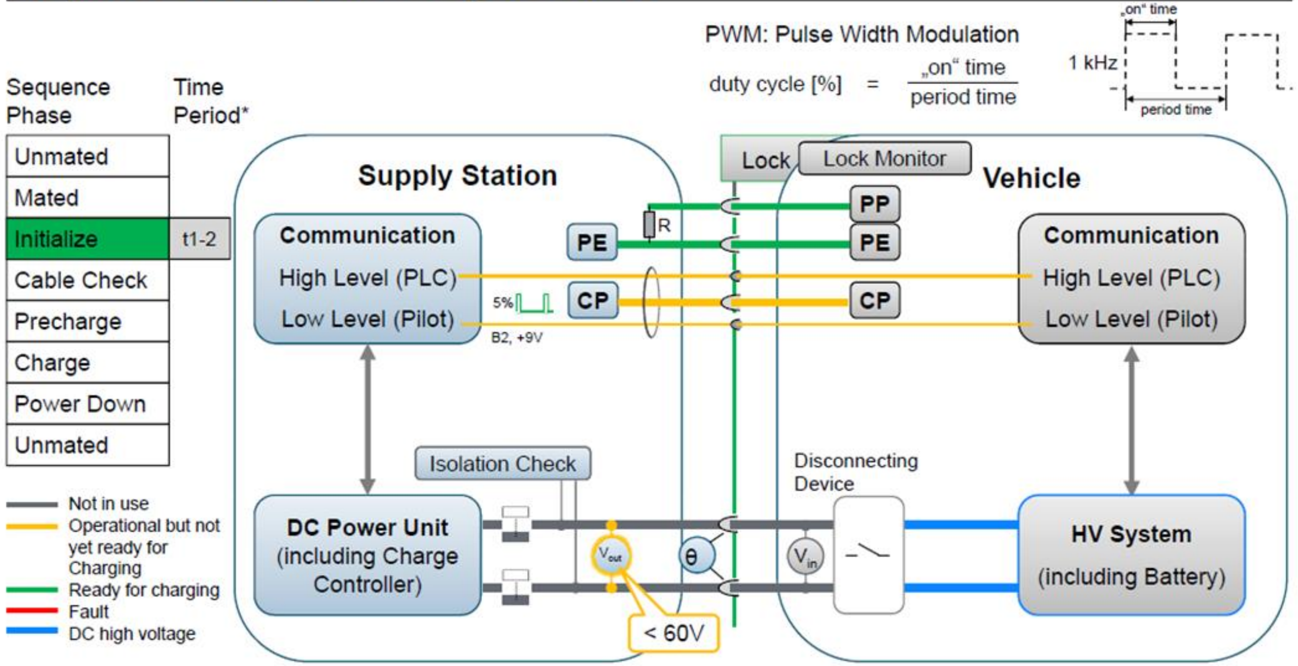


* According to IEC 61851-23

➤ CP enters state B1 instantly with mating. This condition is detected by the 9V signal measured at R1. Vehicle is immobilized (PP).

IEC 61851 – safety related standard for EV charging

Illustration of charging sequence with a simplified architecture on system level



> Establish PLC communication: Exchange operating limits and parameters of charging. Shutdown if d.c. Voltage > 60V or incompatibility of EV and d.c. supply is detected.

Control Pilot System Functions

State A +12V	▪ No coupler engagement
State B +9V	▪ Coupler engagement detected ▪ Vehicle not yet ready ▪ EVSE supply energy: Off
State C +6V	▪ Vehicle ready ▪ EVSE supply energy: On
State D +3V	▪ Vehicle ready ▪ EVSE supply energy: On ▪ Ventilation required
State E +0V	▪ Short of CP to PE (connection lost) ▪ Unlock plug after max. 30ms
State F -12V	▪ EVSE not available.

IEC 61851 – PWM and PLC

PWM signal on CP pin at 1kHz, duty cycle defines value of charging current.
Amplitude corresponds to State of EV – EVSE coupling.
High level communication on PLC according to standard HomePlug GreenPHY, with 2-30 MHz band

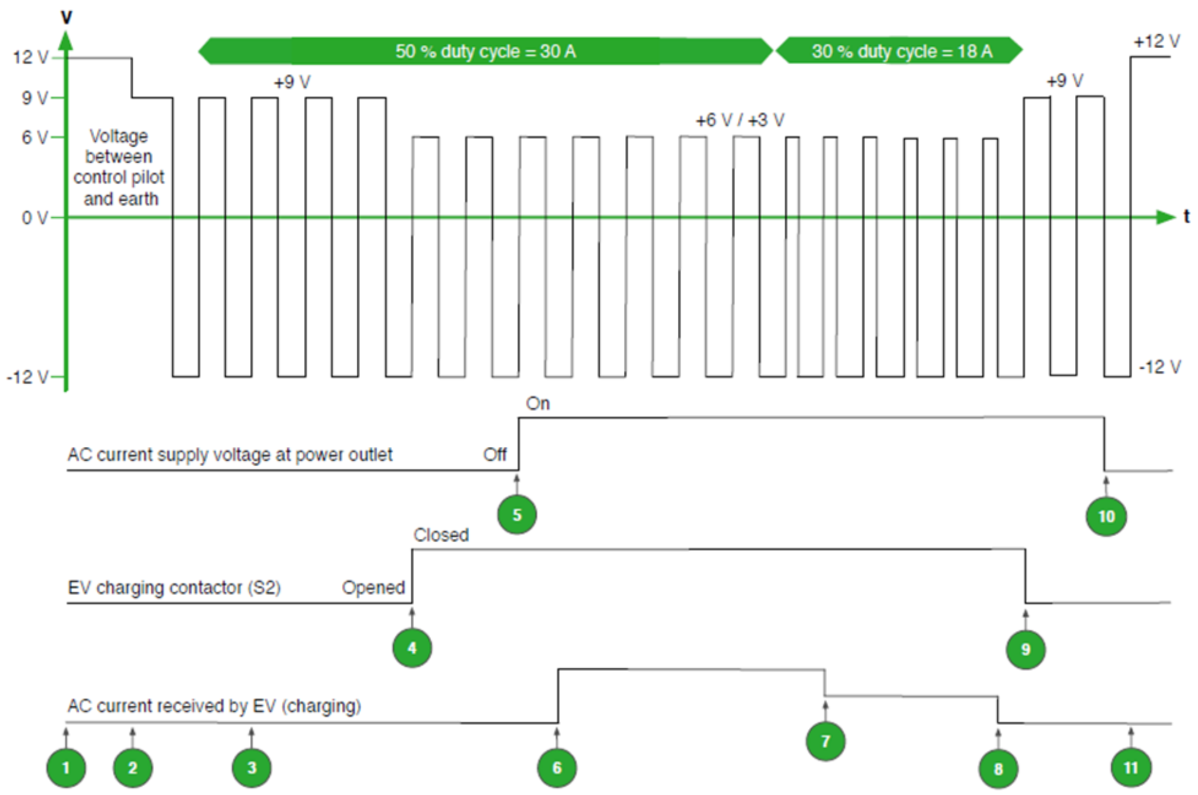


Figure 2.7.: Example of a charging session illustrated by means of a pulse-width modulated signal (inspired by [1], Annex A)

Communication Protocols in ISO 15118

The operating principle of the OSI model is:
communication between two endpoints in a network is divided into seven groups of functions or layers.

The communication between EV and charging station to charge the battery, involves:

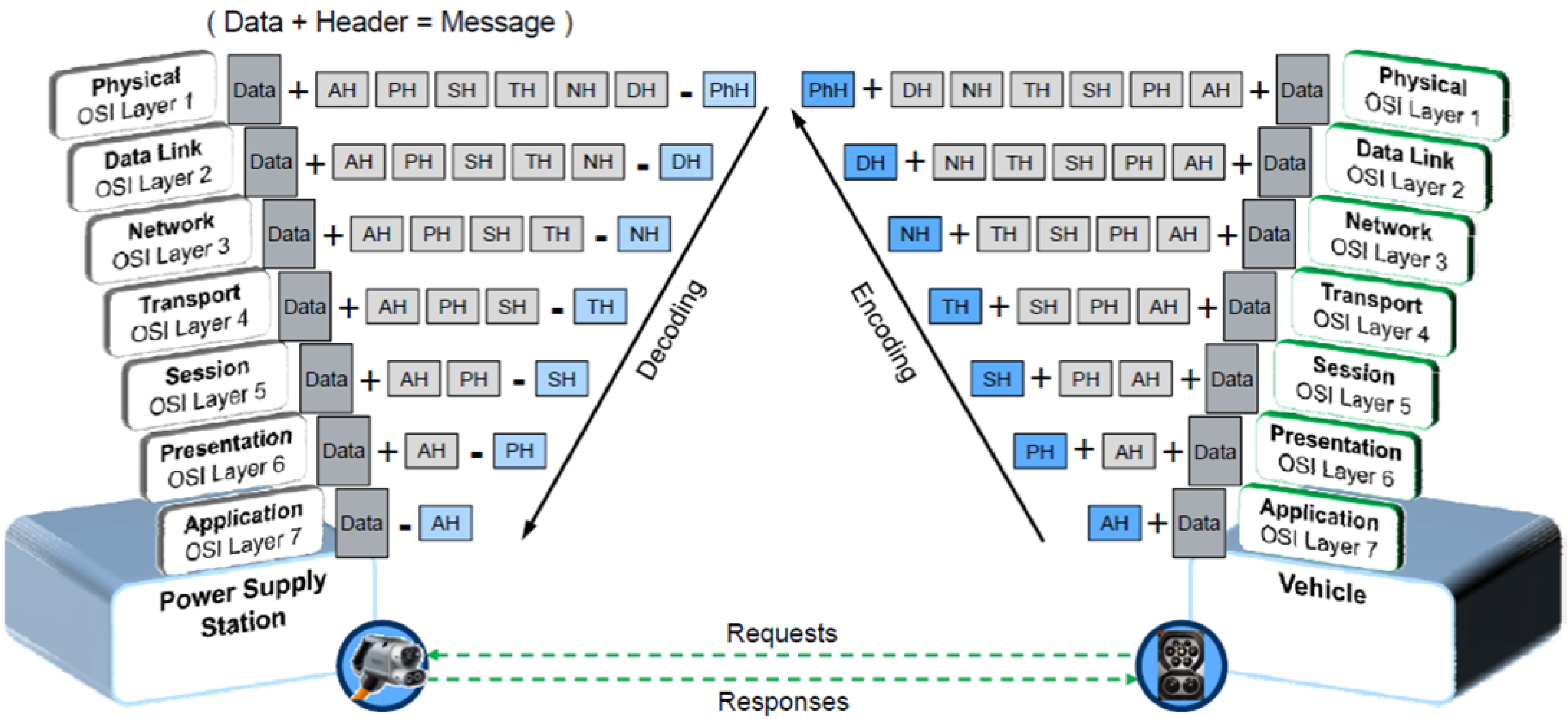
- **Electric vehicle communication controller (EVCC),**
- **Supply equipment communication controller (SECC).**

The EVCC's message will be processed on the EV side by all functional layers, starting with the application layer and all the way down to the physical layer.
Once the message has traversed to the bottom layer, the EV sends the data to the charging station using a physical medium like a charging cable or a WiFi connection.
On the receiving end, the charging station will go through the same steps but in the opposite direction.
The complete data packet traverses from the bottom physical layer up to layer seven – which is called the application layer.

Communication Protocols in ISO 15118

Illustration of High Level Communication

OSI-Layer-Model: Package Assembling



- During the communication process each Layer is encoding (addition) or decoding (subtraction) the layer specific header.

PEV and EVSE exchange power and information

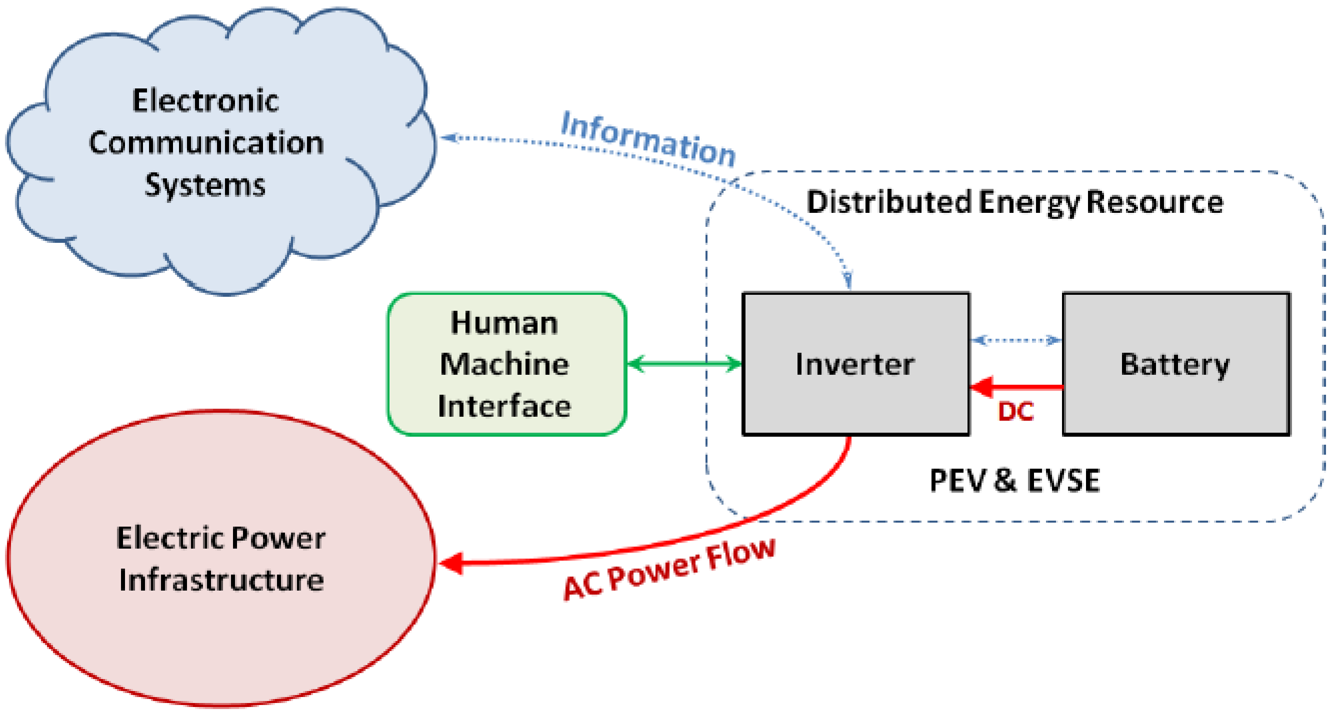


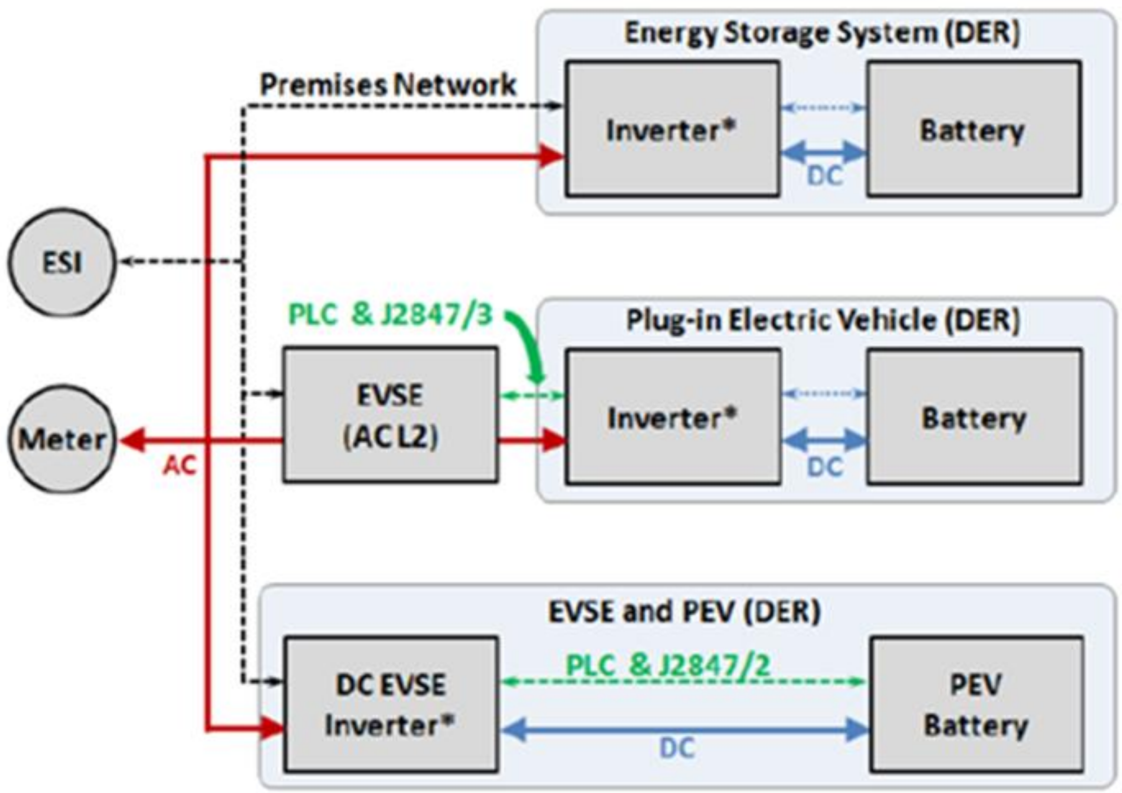
Figure 9 - Interfaces with inverter of a DER device

Diagram from standard SAE J2836

AC and DC Charging

AC-EVSE, when inverter is in the PEV (Plug-in EV)
DC-EVSE, when inverter is in EVSE

Diagram taken from **SAE J2836/3** “Use Cases for Plug-In Vehicle Communication as a Distributed Energy Resource”
PLC (Power Line Communication, green lines) is used to exchange information with inverter:



DER = Distributed Energy Resource

3 cases are shown:

- **DER = ESS**
  Stationary Energy Storage System
- **DER = PEV**
  PEV = Battery + Inverter
  On-board Inverter (*)
- **DER = PEV + EVSE**
  Off-board inverter in EVSE (*)

(*) Bidirectional Power Transfer (BPT) is provided

BEV technology

Performance improvements are expected in these areas:

- **Battery life** (8-10 years, 100,000-150,000km)
- Cost of the BEV vehicle
- **Charging time**

  (8h with slow charge at 3kW AC, **30min with fast charge 50kW DC**)
- Autonomy (200km with 30kWh battery)
- Battery energy density (more energy with the same weight and volume)

Reference to an average BEV vehicle, similar to the Nissan Leaf, the best-selling in the world, or Fiat 500e

DC Fast Charge of EV

Range (km) and charging time are critical factors per PEV user
Fast-charging stations along motorways, in service areas, are expected to be deployed in near future
Charging, desired duration: max 15 minutes

The **RTE or cycle efficiency** of a lithium-ion battery, with 1C charge / discharge rate, including power converters, is about 90%, if referred to AC–AC, higher than 96% if referred to DC-DC.

The energy losses during charge / discharge depend on the C-rate.
It is proportional to C-rate, at 2C is twice than at 1C
The energy yield is lower with higher C-rates.

Numerical example:

EV battery capacity : 100kWh
Series resistance : 0,032 ohm
Rated voltage : 400V
DC-DC cycle efficiency : 96%
Rated current : 250 A (1C)
Loss power : 2kW (at 1C)

Battery temperature rise has to be checked, because it is related to loss power

C-rate	current	time	Energy Loss	Loss Power
1C	250 A	60 min	2 kWh	2 kW
2C	500 A	30 min	4 kWh	8 kW
4C	1000 A	15 min	8 kWh	32 kW

IEEE Std 2030.1.1-2015
IEEE Standard Technical Specifications of a DC Quick Charger for Use with Electric Vehicles

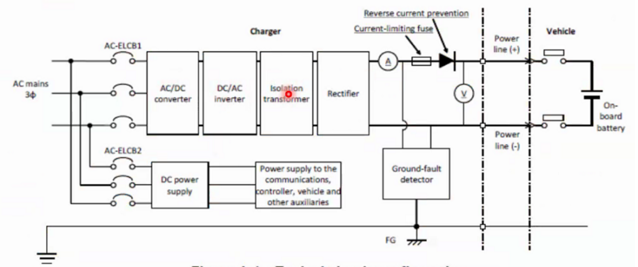


Figure A.1—Typical circuit configuration

DC Fast Charge of EV

Numerical example - continues

		1C	2C	4C
Capacity	kWh	100	100	100
Series Resistance	ohm	0,032	0,032	0,032
Charge current	A	250	500	1000
Rated voltage	V	400	400	400
Thermal Capacity	kJ/ K	720	720	720
Specific heat	J/kg K	800	800	800
Weight	kg	900	900	900
Thermal exchange area	m2	0,5	0,5	0,5
Thermal exchange coefficient	W/m2 K	1000	1000	1000
Thermal resistance	K/W	0,002	0,002	0,002
Thermal time constant	s	1440	1440	1440
Loss power	W	2000	8000	32000
Delta T steady conditions	K	4	16	64
Delta T at end of charge	K	3,7	11,4	29,7
Charge time duration	s	3600	1800	900

V2X – EV connections to discharge power, if a bidirectional power flow is allowed

Use case	View	Functionality
V2L Vehicle to Load		For powering external loads, like water boiler, TV, refrigerator, pump water, etc.
V2H Vehicle to Home		Emergency supply (UPS) for stationary installation at home supplying the energy in case of grid failure
V2H Vehicle to Home		Home supply. Optimization regarding energy costs, RES integration, energy arbitrage, time shift, energy peak reduction and demand flattening.
V2G Vehicle to Grid		TSO services: Participation in the primary and secondary frequency regulation.
V2G Vehicle to Grid		Future DSO services: reactive compensation, voltage regulation, deferral investment, energy losses reduction, short term congestions, post fault management.

V2X – EV connections to discharge power, in presence of bidirectional power flow

VEHICLE TO GRID (V2G)

When vehicle power is fed into the bulk electric grid or a microgrid, we refer to it as **"Vehicle-to-Grid"** power, or V2G. A PEV in V2G operation is considered by utilities to be a **Distributed Energy Resource (DER).** V2G is based on bidirectional flow. **V2G-AC** designates the use of an onboard inverter feeding AC power back through the EVSE. **V2G-DC** designates the use of DC current from the PEV battery with an inverter located in the EVSE.

VEHICLE TO HOME (V2H) USING AN ON-BOARD INVERTER

Vehicle to Home describes the capability of a vehicle to act as a **backup "generator"** for selected critical loads in a home isolated from the power grid, for example, after the failure of the power grid. The vehicle on-board inverter regulates the voltage and frequency and the power flow is routed to NEMA receptacles on the **vehicle exportable power panel**. A power cord plugs into a NEMA receptacle on the vehicle panel and to the home's electrical service through a transfer switch that isolates the critical loads to be powered by the vehicle from the grid.

VEHICLE TO LOAD (V2L) USING AN ON-BOARD INVERTER

Vehicle to load means the transfer of energy from the Vehicle to a Load. This can be used **to support power to tools and other items** not connected to a home or the grid. The vehicle on-board inverter regulates the voltage and frequency and the power flow is routed to NEMA receptacles on the **vehicle exportable power panel**.

Text from standard SAE J2836

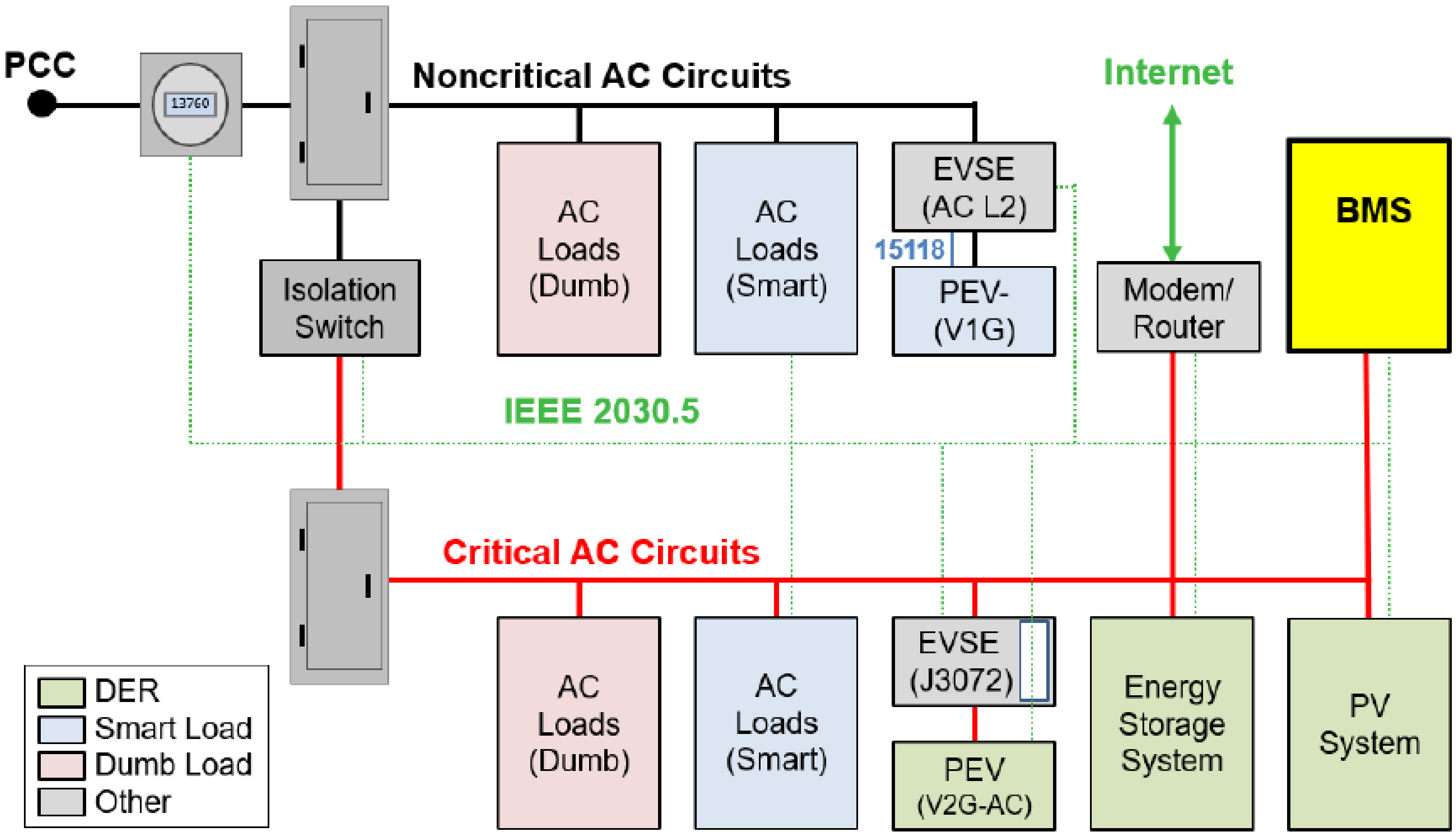


Figure 6 - VGI model - Smart building integration

Diagram from standard SAE J2836

V2B = Vehicle to Building

Properties of PEV Batteries (Plug-in Electrical Vehicle)

The PEVs are equipped with lithium-ion batteries, characterized by
Stored capacity or energy, in kWh. It changes with degradation of battery due to aging.
Useful life, expressed by the number of equivalent charge / discharge cycles up to achievement of 80% of the initial capacity
The **State of Health (SoH),** which measures the remaining battery life

The useful life depends on two aging factors:

- **Calendar**, time function, temperature, SoC (State of Charge)
- **Cyclic operation**, mainly measured by energy throughput or from the number of equivalent cycles, it also depends on C-rate, SoC, ...

Battery aging involves:

- Reduction of capacity
- Increase of series resistance, with decrease of useful power

Estimated battery availability for V2G

The life consumption of the PEV battery is to be divided between "driving" the vehicle and "network services" remunerated with V2G
The useful life of the battery depends on the **calendar and cyclic aging**.
The limits set by cyclic aging, associated with the use of the battery, are expressed by the **Energy Throughput**, or by the number of cycles, guaranteed by the manufacturer.

Simplified numerical example of Energy Throughput calculation, with zero power losses

40kWh battery, guaranteed for 2000 cycles with 80% DoD has a total throughput of:
ET = 40 x 2000 x 0.8 = **64 MWh**

Driving quota: 150,000km x 0.18kWh / km = **27MWh**

Quota available for V2G: 64 - 27 = **37 MWh**

Smart Charging and V2G. Multi charging port stations

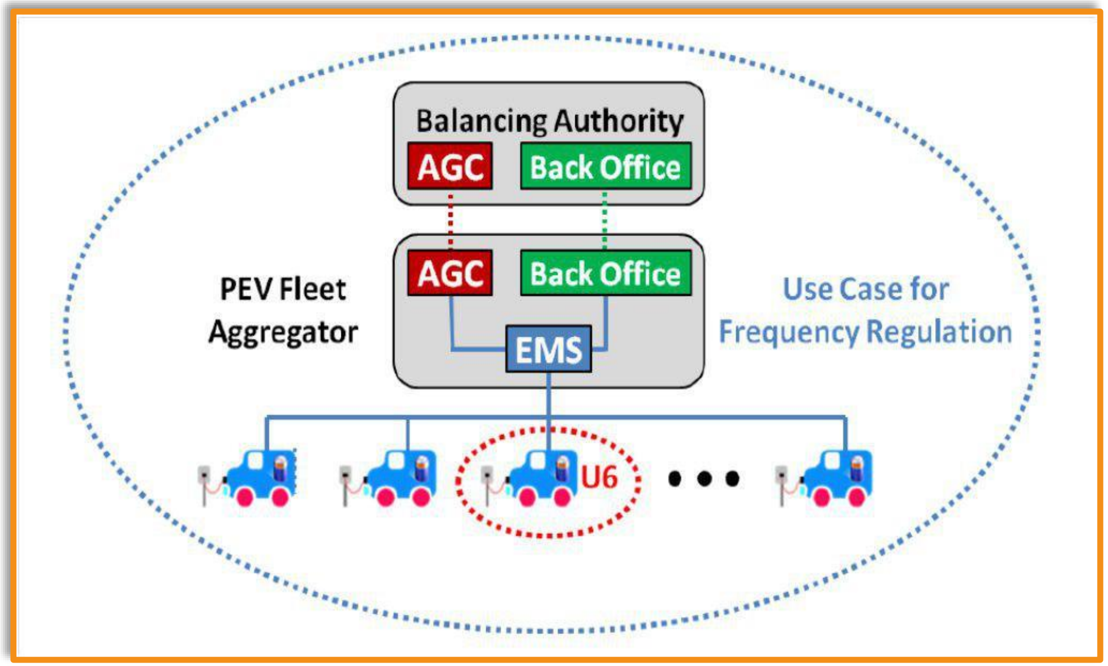
Multi charging port stations.

EV Fleets
Large Facilities:

- parking lots,
- shopping centers,
- corporate campuses,
- hotels and resorts
- public buildings

(hospitals, schools, military, government)

Service petrol stations
Multi dwelling units,
Large residential buildings
Residential houses



EV Charging Stations

Composition of EV DESS

- **EV Charging Stations**, including several **AC-EVSEs or DC-EVSEs**, equipped with a BESS or not, capable to perform V1G, V2G and V2X functions
- **EV individually connected to grid by an EVSE**, controlled by a common Aggregator

The EV charging infrastructure shall integrate the **CS electrical power system and its control and communication network.** The IS shall cover the various system configurations

Configurations of EV Charging Stations

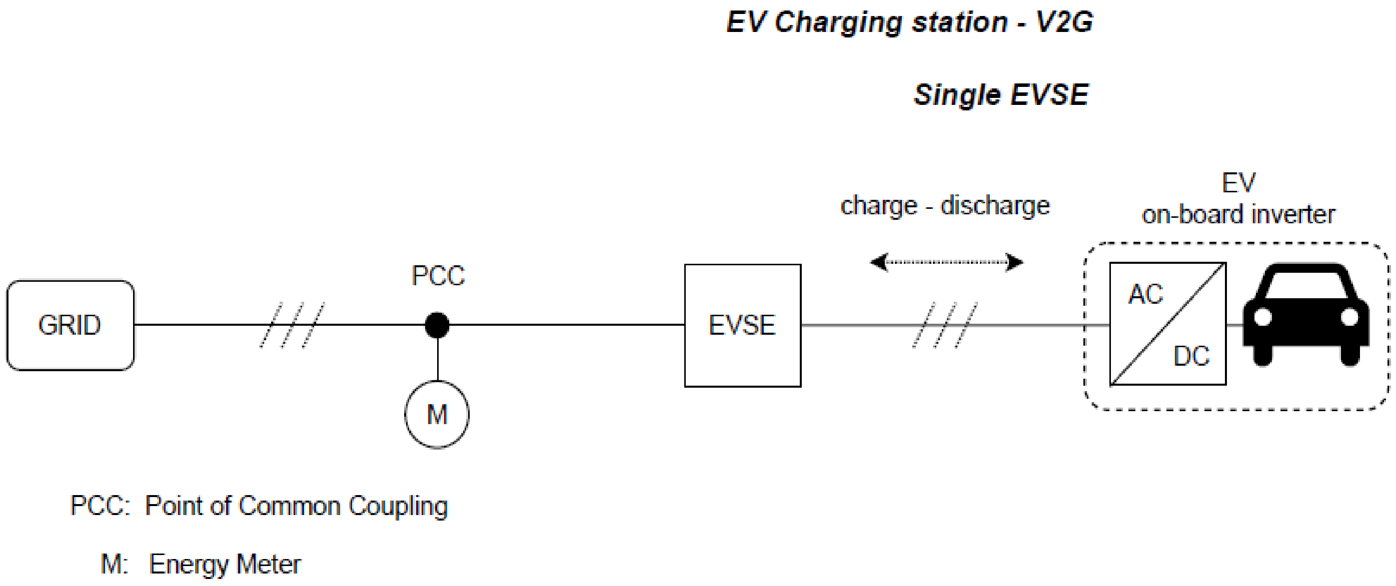
They can be different according to following features:

- Charge and discharge, with **mono or bidirectional** power flow between EV and EVSE
- **One or more EVSEs** in one EV-Charging Station
- **AC or DC bus** configurations, in presence of multiple EVSEs
- Bidirectional inverter **on-board** of vehicle **or off board**

EV Charging Station - Configurations

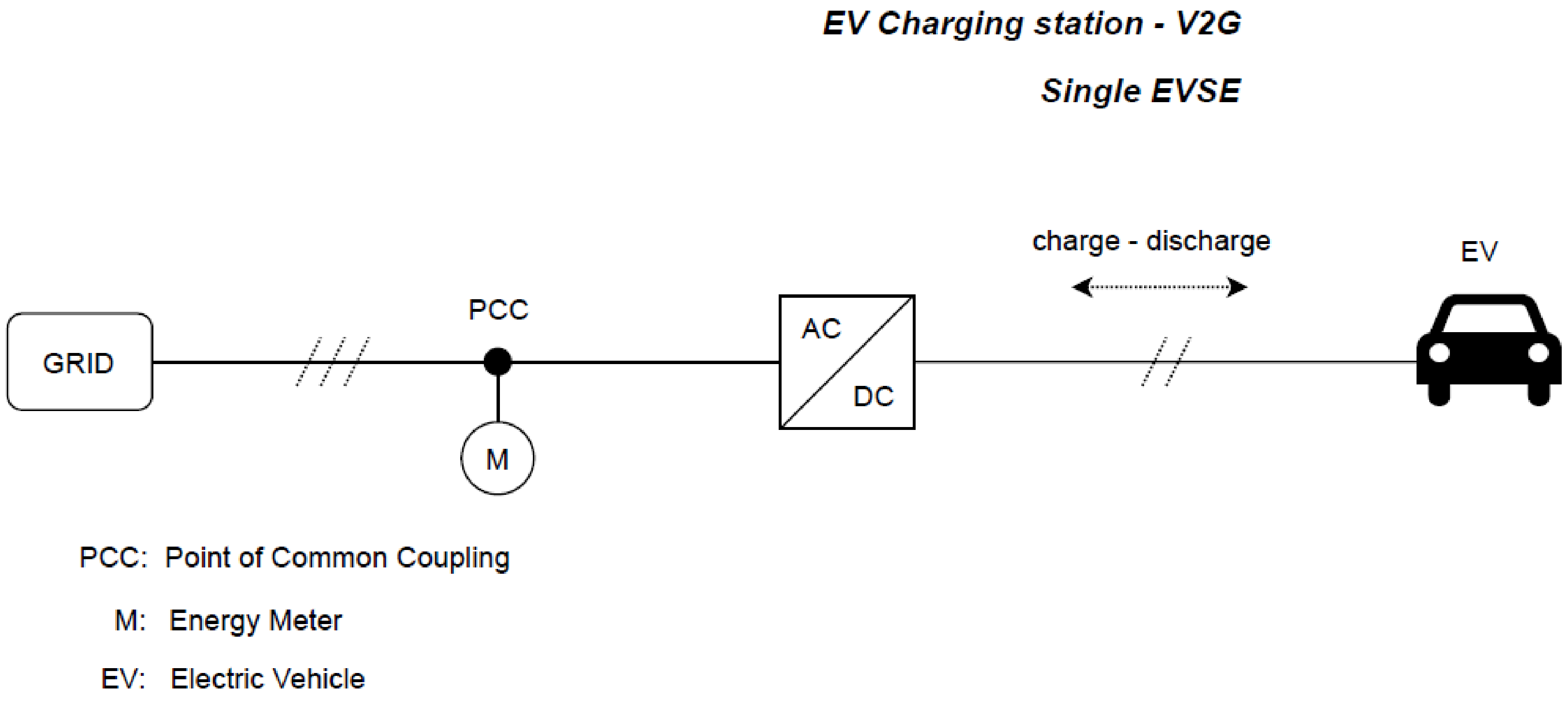
Example:

a simplified V2G configuration is illustrated, using an on-board bidirectional converter



EV Charging Station - Configurations

As an example, some simplified V2G configurations are illustrated, using off-board bidirectional converters



EV Charging Station - Configurations

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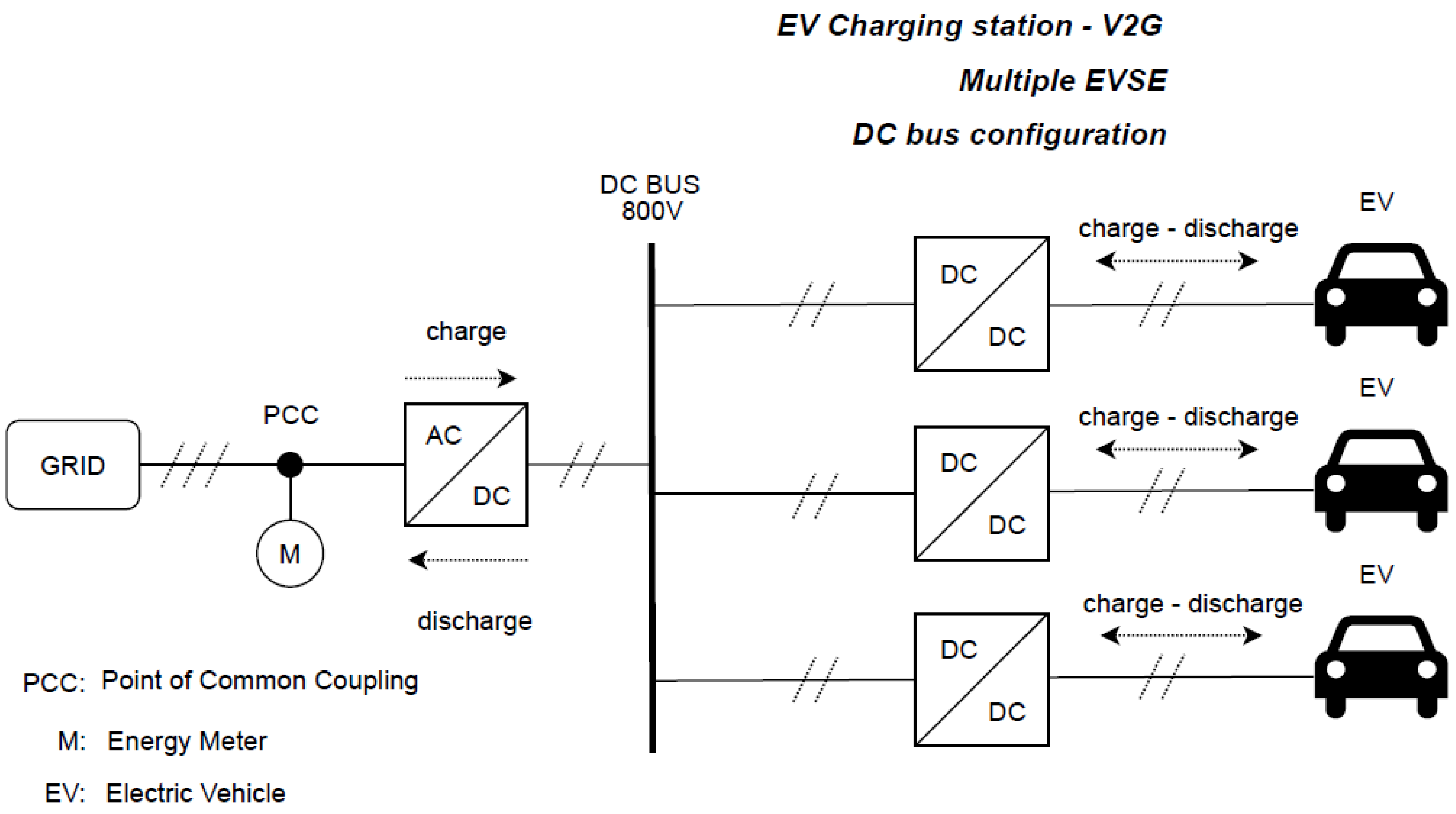

EV Charging Station - Configurations

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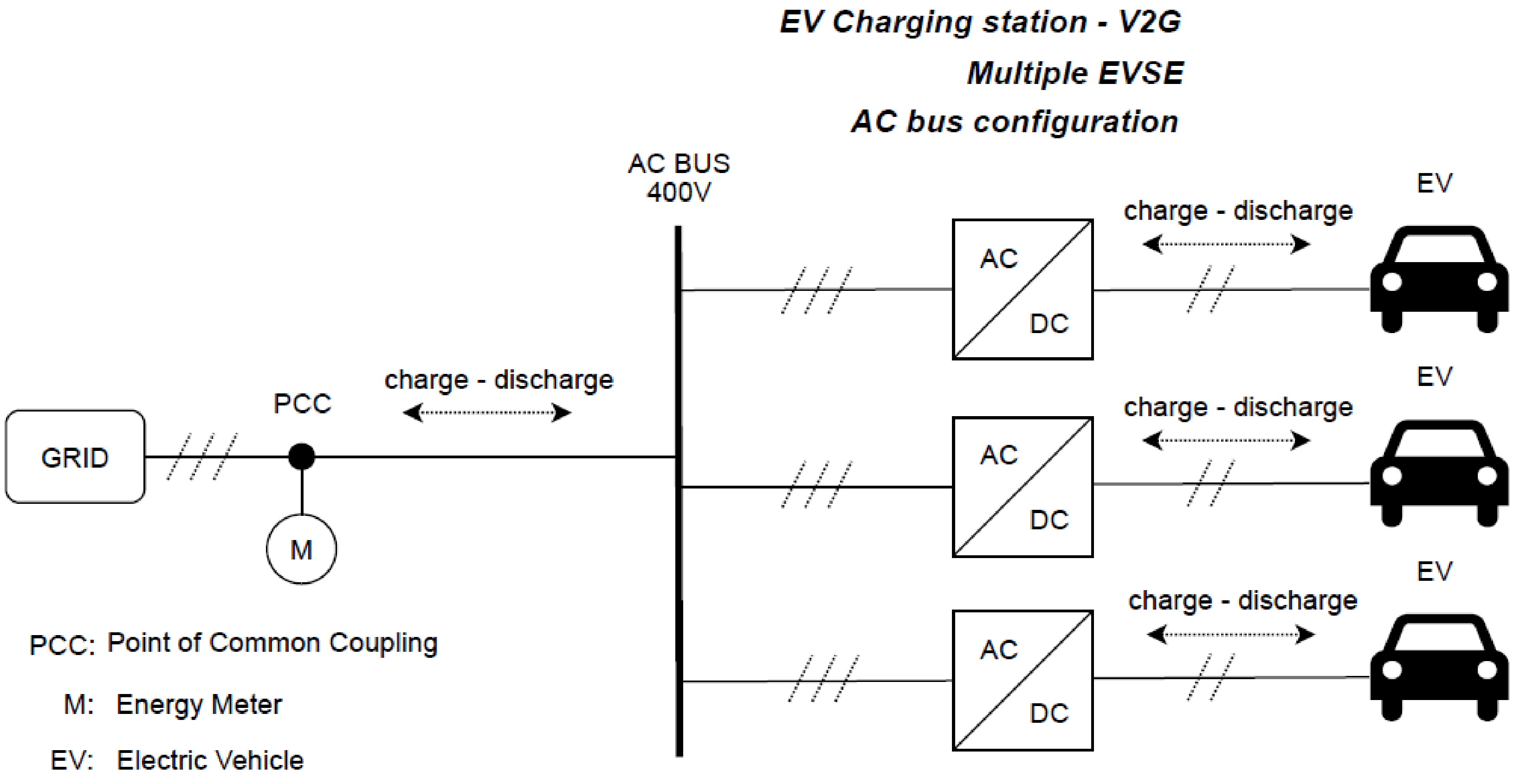


Operation and control of an EV Charging Station with DC bus configuration

DC bus configuration
The EV Charging Station (CS) has only one PCC to grid.
A **bidirectional smart inverter** (DC-AC) connects the CS to the PCC.
A common DC bus is kept at a **constant dc voltage** (at a level between 700 and 800V).
The EV CS consists of several EVSEs.
Each EVSE contains one (or more) DC-DC converter, see next slides for technical description of DC-DC converter.

Control of power flow
Each converter is equipped with a microcontroller (HW+FW), which manages the operation of its converter and generates the PWM signals to power semiconductors devices (IGBT) of converter.
The embedded FW of inverter microcontroller implements the **main functions of grid code**.
All microcontrollers are connected to a higher level of control, which may be called **Master Controller**.
Master Controller manages the power flows in the Charging Station facilities.
It communicates with the **Customer Energy Manager, CEM** (or it may be part of the CEM).
It calculates the set points to be sent to all the converter microcontrollers.

Battery and DC-DC converter
Each DC-DC converter controls the charging (or discharging) current of EV battery, so that it follows the target current (**setpoint from Master Controller**).
To do so, it adjusts the dc voltage applied to EV battery.
The EV battery can be considered equivalent to a dc generator with a series resistance.
The EV battery voltage may vary in a **range 250V – 400V**.
The OCV (Open Circuit Voltage) of dc generator depends on SoC of battery. Battery voltage depends on OCV plus voltage drop on series resistance. At the same SoC, during charge process the battery voltage is higher (up to 400V), during discharge battery voltage is lower (down to 250V).

The inverter operates in **grid following mode**, generating active power P and reactive power Q according to setpoints imposed by Master Controller.

Diagram from IEC 62909-2 - Grid Connected Power Converter (GCPC)

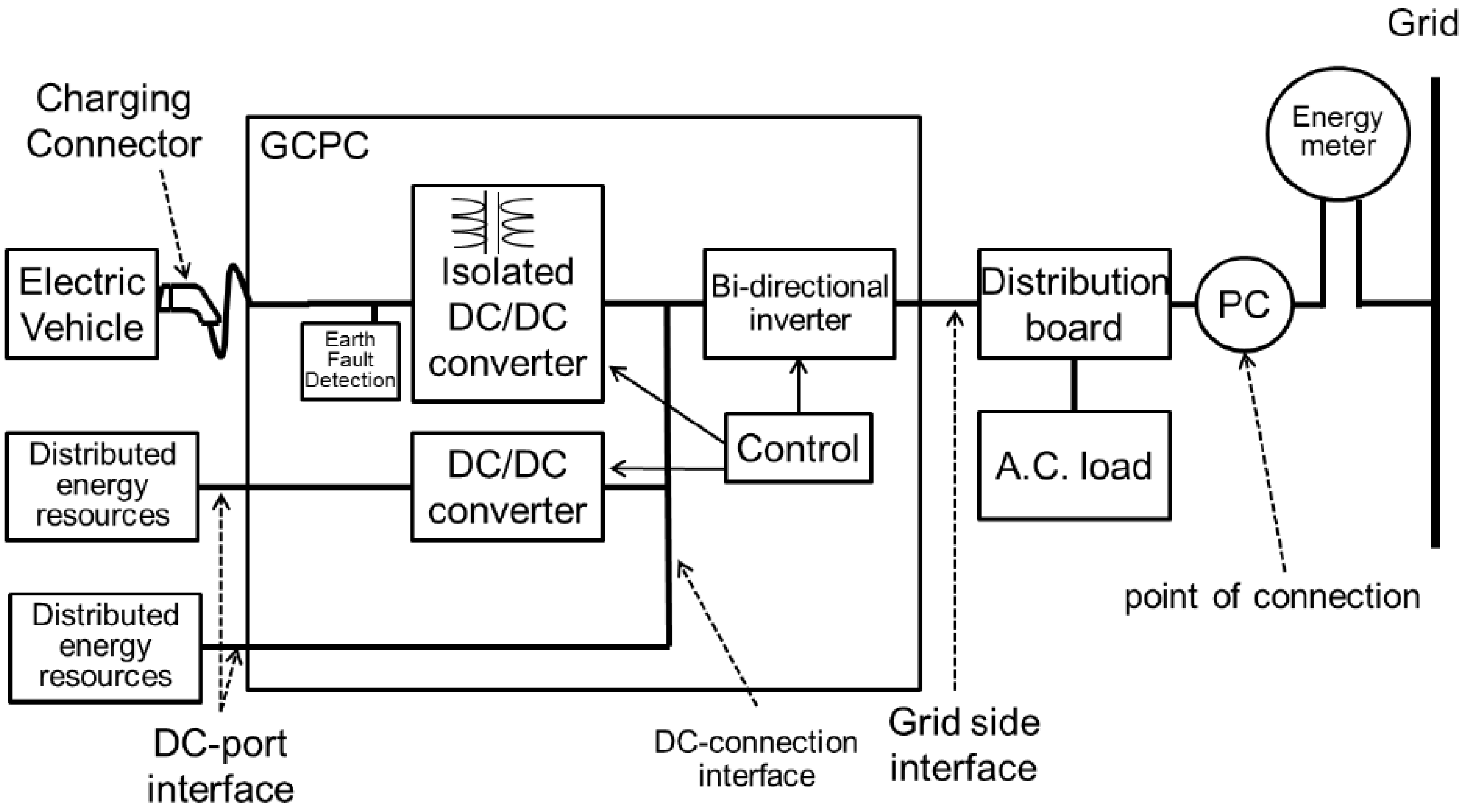


Figure 3 – GCPC with an isolated dc/dc converter in its EV section

DC-DC power converter

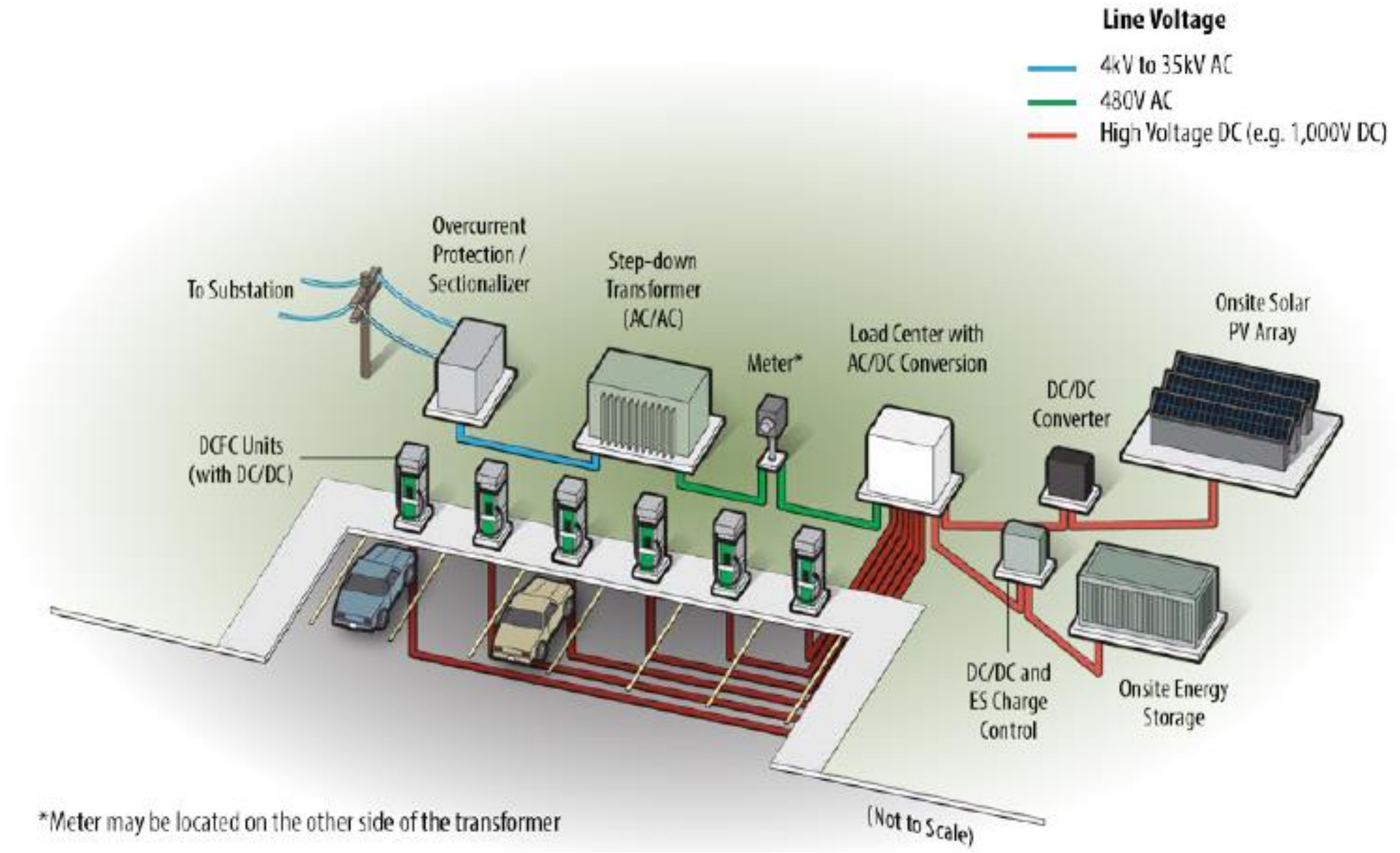
Bidirectional power flow.
Galvanically Isolated by a medium frequency power transformer.
Two-stage configuration with two active single-phase bridge.

In a DC Bus EV Charging Station it has the purpose to charge/discharge the EV battery
It is located in the EVSE box and it connects to the Dc bus.

Typical voltages
DC bus at 800V constant
EV side: 250V – 400V

Multi Charging Point Station

Multi charging station. With Energy Storage, several DC-DC EVSEs connected to a DC bus



Multiport EV Charging Station with PV Generation and Energy Storage

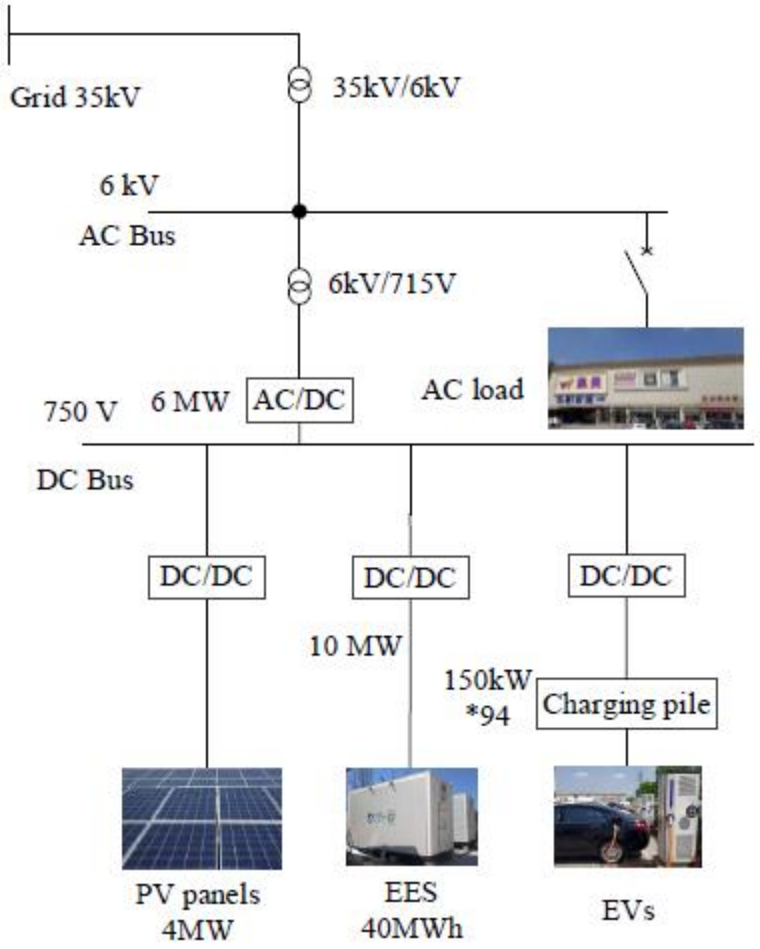


Diagram refers to a large EV Charging Station including:

- n. 94 DC Fast Chargers, rated 150kW each
- 10MW / 40MWh stationary Energy Storage
- 4MW Photovoltaic power plant
- AC load fed at 6kV
- n.1 AC-DC converter, rated 6MW
- AC bus at 6kV
- DC bus at 750V
- Step-up transformer 35kV / 6kV
- Grid connection at 35kV

The EV charging station is located in Fengtai-China

Diagram and technical data taken from IEC TR 62933-2-200

Recommended technical literature – EV Chargers

A 10 kW Solar-Powered Bidirectional EV Charger Compatible With Chademo and COMBO

Authors: Gautham Ram Chandra Mouli , *Member, IEEE*, Jos Schijffelen, Mike van den Heuvel, Menno Kardolus,
and Pavol Bauer, *Senior Member, IEEE*

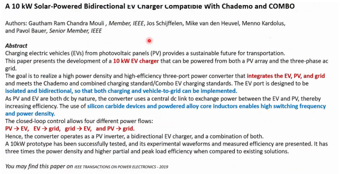
Abstract
Paper presents the development of a **10 kW EV charger** that can be powered from both a PV array and the three-phase ac grid. The goal is to realize a high power density and high-efficiency three-port power converter that **integrates the EV, PV, and grid**.

You may find this paper on IEEE TRANSACTIONS ON POWER ELECTRONICS – 2019

EV Charging Solutions – Power Electronics – NUBE Brochure

It includes technical data and description of a large variety of EV Charging Stations, by the company Power Electronics

https://www.power-electronics.co.nz/assets/brochures/20190219-Nube-Brochure-07-WEB.pdf


A 10 kW Solar-Powered Bidirectional EV Charger Compatible With Chademo and COMBO

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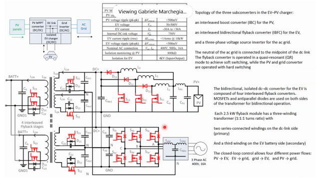
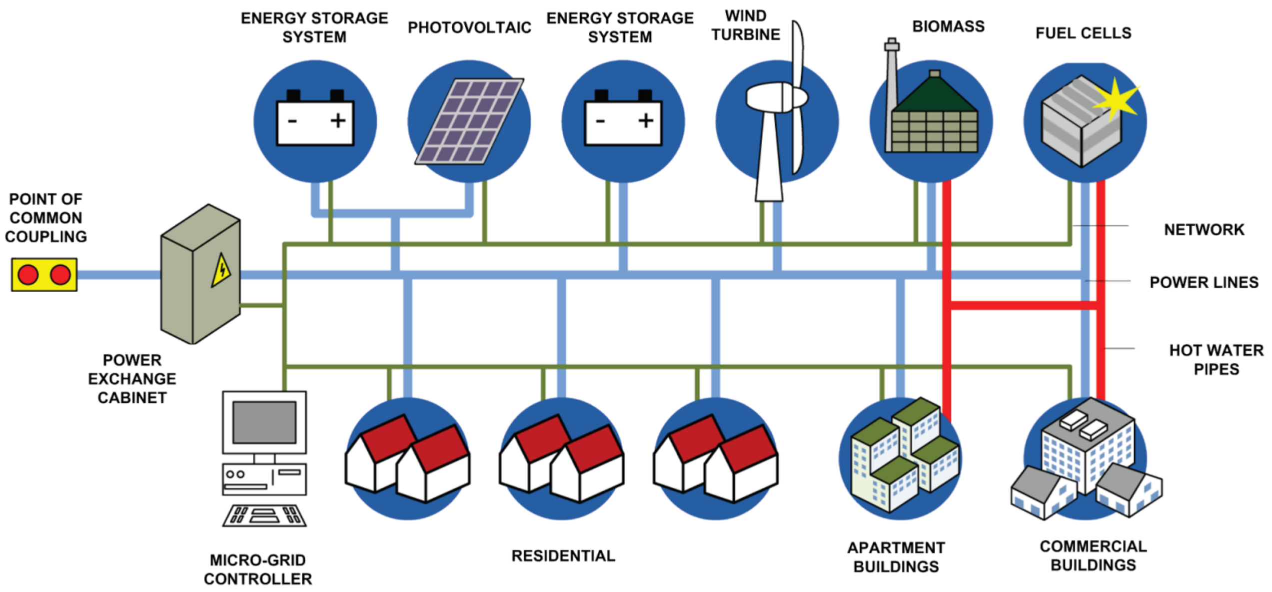
Abstract
Charging electric vehicles (EVs) from photovoltaic panels (PV) provides a sustainable future for transportation.
This paper presents the development of a **10 kW EV charger** that can be powered from both a PV array and the three-phase ac grid.
The goal is to realize a high power density and high-efficiency three-port power converter that **integrates the EV, PV, and grid** and meets the Chademo and combined charging standard/Combo EV charging standards. The EV port is designed to be **isolated and bidirectional, so that both charging and vehicle-to-grid can be implemented.**
As PV and EV are both dc by nature, the converter uses a central dc link to exchange power between the EV and PV, thereby increasing efficiency. The use of **silicon carbide devices and powdered alloy core inductors enables high switching frequency and power density.**
The closed-loop control allows four different power flows:
PV → EV, EV → grid, grid → EV, and PV → grid.
Hence, the converter operates as a PV inverter, a bidirectional EV charger, and a combination of both.
A 10kW prototype has been successfully tested, and its experimental waveforms and measured efficiency are presented. It has three times the power density and higher partial and peak load efficiency when compared to existing solutions.

You may find this paper on IEEE TRANSACTIONS ON POWER ELECTRONICS - 2019



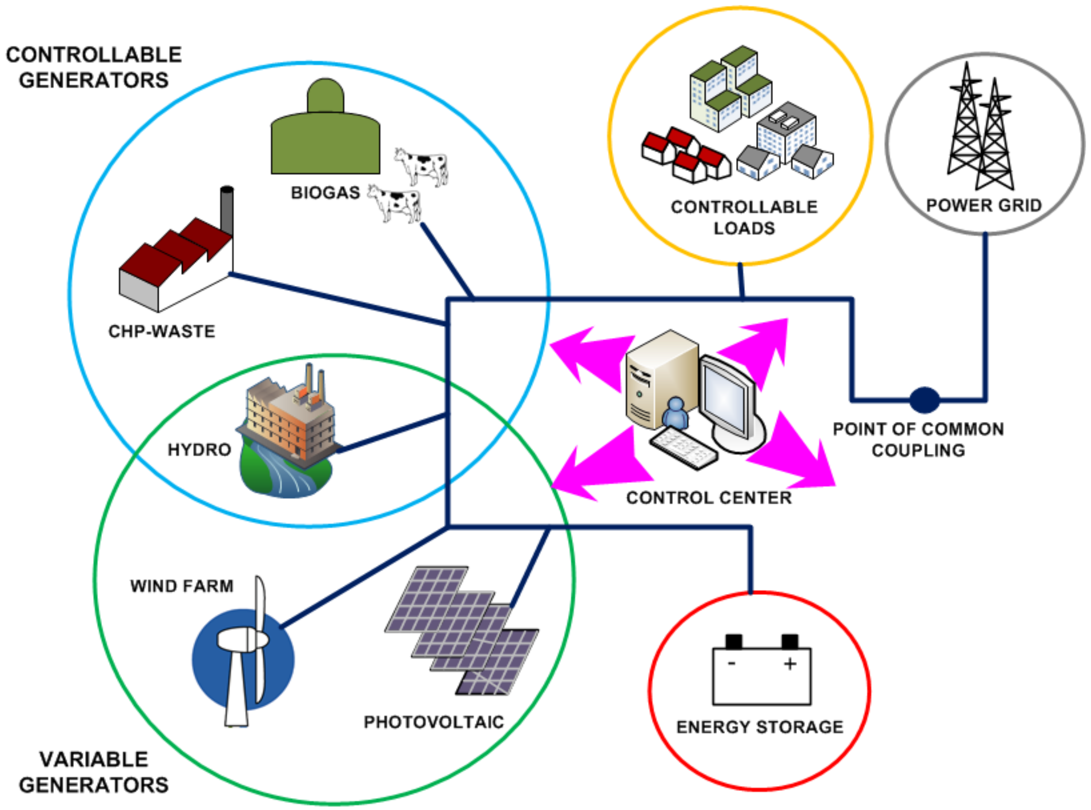
Micro Grids

Micro Grid is a **group of interconnected loads and DERs** which can be connected to the main grid and act as a single controllable entity, by exchanging active (P) and reactive (Q) power with it.
It serves up to thousands of users and it is ideal **to integrate RES**.
The Micro Grid can also work **isolated,** either on a temporary basis (due to a fault on the main grid), or permanently.
In an isolated micro grid the **stability of frequency and voltage**, the **power sharing between generators** must be assured with regulation techniques similar to those normally applied to the main grid.



VPP - Virtual Power Plants

VPPs integrate and coordinate clusters of distributed energy resources (DER), switchable and controllable loads, energy storage, connected by communication links to a Control Center which implements an Energy Management System (EMS)



VPPs behave as conventional power plants, allowing several small DERs and users to participate to the electrical market, improving their profitability and benefits.

Virtual Power Plants in Italy

A new **Regulation of Electrical Dispatch** has been introduced in Italy by a Deliberation of the Authority which opens the electrical market to VPP.

The Italian Authority of Energy has issued the **Deliberation 300/17** on the 5th May 2017 which opens the market of Dispatch Services or ancillary services to the grid, in conformance to the new European regulations about the Power Balancing.

Basically it opens the Italian MSD (Market of Dispatch Services) to the participation of Virtual Units and it introduces the Aggregator or Balancing Service Provider.

It will be possible to have Virtual Units of Generation and Consumption, including energy storage.
Pilot projects are foreseen and they will be managed by TERNA, the Italian TSO.

VPPs in Italy – UVAP, UVAC, UVAM

VPPs have been formally introduced in Italy by the introduction of **“Enabled Virtual Units”,** the threshold of minimum power has been reduced to 1 MW. They are defined UVAP, UVAC, UVAM.

NON-relevant production units (Power <10MW)
Direct access or through an AGGREGATOR (Balance Service Provider) according to specific **provincial perimeters**

• **enabled virtual production units (UVAP),** characterized by the presence of only units of non-relevant production (whether programmable or non-programmable), including the systems of energy storage;

• **enabled virtual consumption units (UVAC**), characterized by the presence of consumption units only

• **mixed virtual enabled units (UVAM),** characterized by the presence of both non-relevant production units (whether programmable or non-programmable), including accumulation systems, or units of consumption

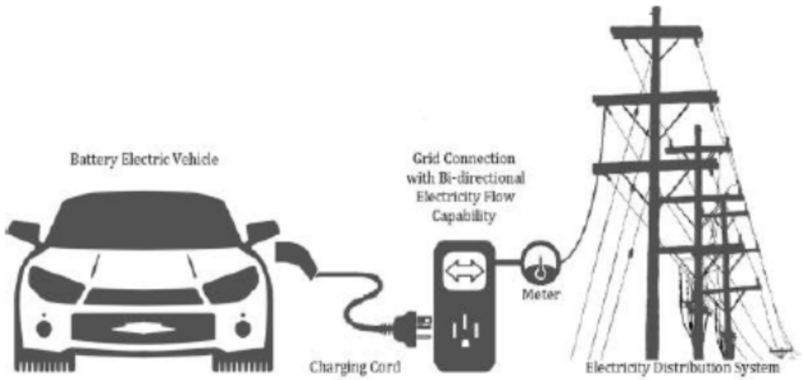
VPPs in Italy – UVAM and V2G

Terna (Italian TSO) has announced that UVAM may include also energy storage systems associated to e-mobility.
Electrical Vehicle charge/discharge infrastructure may be part of a UVAM and in this way the Vehicle to Grid technology will be enabled and be allowed to participate to the remunerated Dispatch Service Market (MSD).

Partecipazione del V2G al MSD

Rientrano nel progetto pilota UVAM anche i **sistemi di accumulo funzionali alla mobilità elettrica**, essendo questi del tutto equiparabili – con riferimento ai punti di connessione alla rete presso i quali avviene la carica / scarica – ad altri sistemi di accumulo

Il progetto pilota UVAM per la prima volta abilita la tecnologia «*vehicle to grid*» (V2G) al MSD



VPP – Coordinate Grid and Market Operations

VPPs is managed by an Aggregator or VPP Operators and consist of

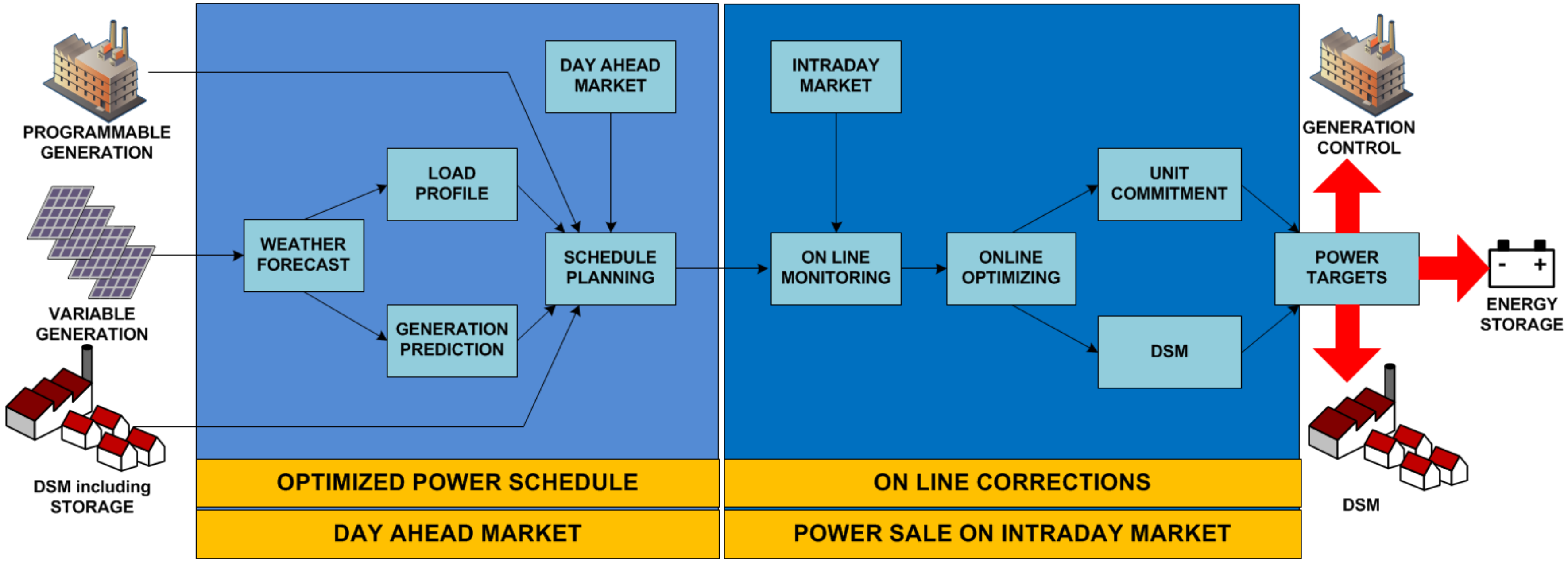
- Control Center
- Data communication links with all components of VPP
- Energy Management System

VPPs allow a high number of actors (small users, IPPs, prosumers) to participate to the electrical market

VPPs can add flexibility to both supply and demand of electricity and contribute to the power grid balancing process

VPPs represent the **"Internet of Energy"**
They contribute to **coordinate the network and market operations** in a smart way.

VPP – Balance Group



VPPs can work as **Balance Groups,** which **optimize** the power schedule on the day ahead market and adjust it by online monitoring, corrections and continuous re-allocation of power resources during the day. Sales of available power on the Intraday market can generate additional revenues.

A VPP requires an **Aggregator/VPP Operator** which can be a Municipal utility, a local DSO, an institution created “ad hoc” by citizens’ cooperative, a local business, an energy trader.

VPP – Business Models

The stakeholders of the VPP shall be compensated by the revenues generated selling grid services and trading power on the electrical market.

Business Models for Virtual Power Plants

- Reduction of the power balancing deviations
- Additional sales income for multi DERs optimization
- Peak load reduction / avoided network charges
- System services: Reactive power supply and voltage control
- Sales of Power on Intraday Market
- Sales of positive/negative Reserve power on the PCR, SCR Market
- Carbon Certificate trade (Maximum use of renewables)

VPP – Demand Side Integration

The adaptation of the demand to the available power generation will gain importance in presence of a higher share of fluctuating power generation from RES.

The control of demand has to be integrated into the power system management.

Demand Side Integration (DSI) can be made in 2 ways :

DSM—**Demand Side Management** is the active switching or modulation of load on a contractual basis with the VPP provider

DSR—**Demand Side Response** is the impact on the consumer behavior by dynamic tariffs