System Architecture for EV used as a DER – V2G AC

EV as a mobile battery storage generating unit – focus on grid codes

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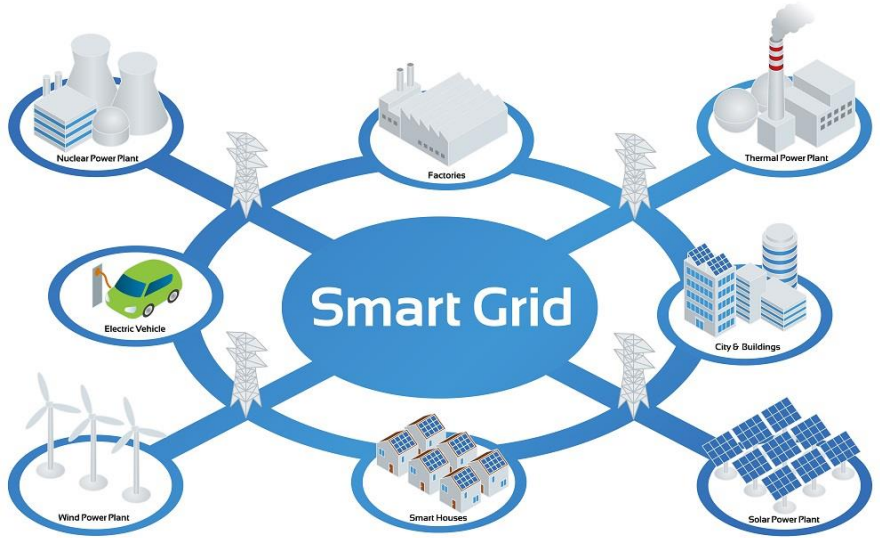
CONTEXT

- **Booming of EV market in Europe and in the world**
  - In France : about 100ku of EVs ➔ 2 GWh
- **Smart grids topics is a major trend**
- **Global interest of public for eco-friendly technologies**
- **Integration of the EVs in the grids could be a risk but also a big asset**



- **Even if a lot of experiments of V2X* and smart charging technologies, use of a mobile DER** remains very challenging**

*V2X = Vehicle to grid, or to home, or to load
** DER = Distributed Energy Ressource

AC

DC

- almost 100% in private
- Low investment
- Charger in every car ➔ “just” need to make it bi-directional

- Big size of the cabinet
- High investment needed
- Mainly for high power / short connection time

➔ V2X will mainly be used at main harbor with AC EVSE

V2X : 2 main use-cases

	Grid connected	Islanded
	EV regulates current	EV regulates voltage
Customer value	High added value (ancillary services, selfconsumption)	Low added value (blackout, isolated installation or socket-only)

V2G Vehicle to grid

V2HG Vehicle to home – connected to grid

V2L Vehicle to load

V2H Vehicle to home – isolated from the grid

➔ Concentrate on Grid connected mode

Grid codes

- Set of rules applicable to any generator connected to the main grid
  - Not to be confused with ancillary services
  - Grid codes are mandatory & not subject to earning

EN50438 and EN50549

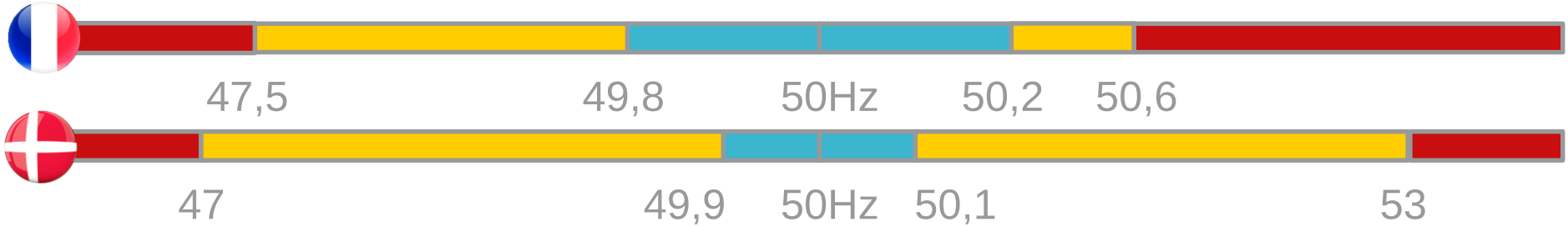
VDE 4105 / DIN 0126

IEEE 1547

- Main functions (ensured by DER)
  - *Anti-islanding*: stop generator when grid drops
  - *Decoupling / Re-connection rules*: generator operates only on stable grid
  - *Response to frequency deviation*: active power adjustment for grid stability
  - *Reactive power compensation*: inject / consume reactive power for grid management
  - *Immunity* of generator to voltage / frequency events

Grid codes are local: country / network operator specific

Grid codes / Ancillary service : Frequency (example)



Ancillary service

- Primary reserve: 50 +/- 0,2 Hz in France
  - Generator provide active power proportional to Frequency deviation
  - Remunerated by TSO

Grid codes

- Response to over frequency: if required, decrease active power
- Response to under frequency: if required, maintain active power
- Decouple / Stop generator

Basic tasks performed by the DER

Setup / Store grid codes parameters

Measure (Freq, Voltage)

Calculate Active and Reactive Power setpoints (P/Q)

Power conversion

Couple / Decouple to rest of the grid

Function allocation: focus on interface protection

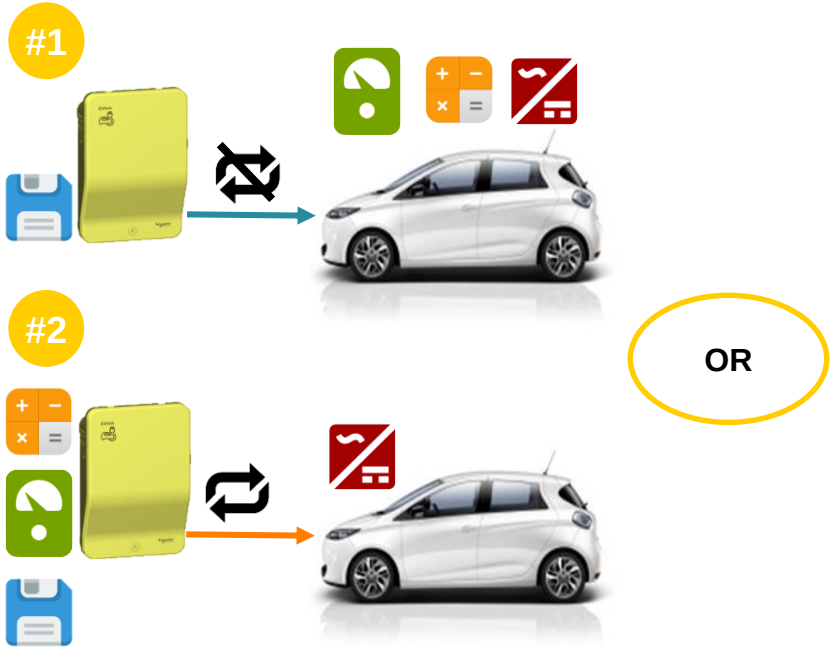
Function	Ensured by	Rationale
Decoupling protection	Installation / EVSE	Local parameters; allows V2H when installed close to POC*
Connection / Re-connection	Installation / EVSE	Access to grid side for measurement
Islanding detection *Passive method*	Installation / EVSE	Passive method based on waveform monitoring *(e.g. ROCOF, Vector Shift)*
Islanding detection *Active method*	Bidirectional OBC**	Active method requires inverter control *NOTE: in some countries, active method is forbidden*

*POC : Point Of Connection

**On Board Charger

Support to Voltage / Frequency: 2 possible architectures

Local parameters > have to be set to the installation (EVSE)



- Requires to communicate complex list of parameters
- Fast reaction possible (measurements done in the inverter)

- EV inverter is a simple slave (P/Q setpoints)
- Reaction speed depends on communication

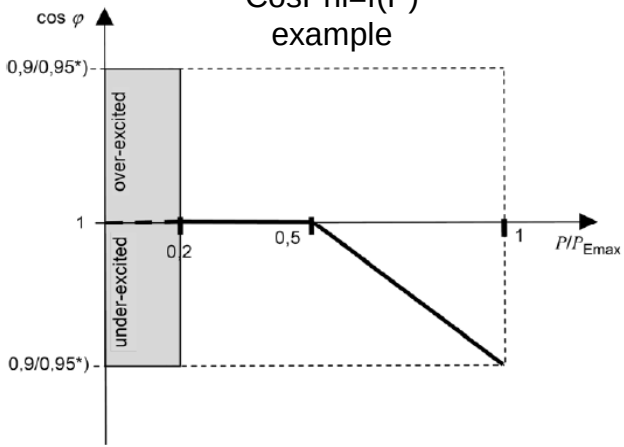
Support to Voltage: Reactive power local adjustment

Support to voltage is realized through local adjustment of reactive power.

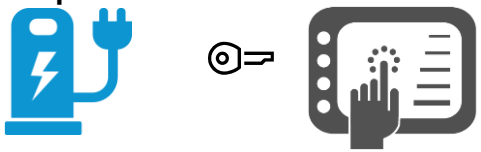
At least 3 modes can be chosen, depending on the DSO's local rules:

- Fixed CosPhi
- Q=f(U)
- CosPhi = f(P)

CosPhi=f(P) example



Step 1 : EVSE installation

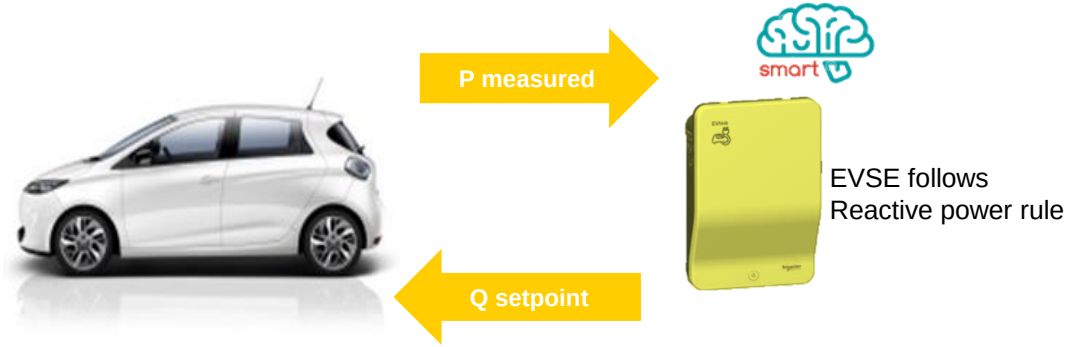


After installation, the electrician selects the right mode and parameters associated in the EVSE HMI with the DSO approval

Support to voltage: Reactive power local adjustment

Step 2 : Power exchange

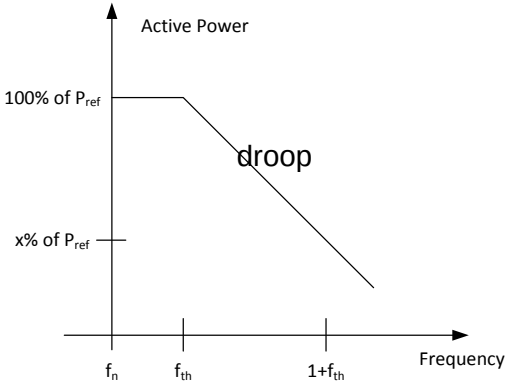
As the EV does not know the local grid codes parameters, it is the EVSE that will adjust the reactive power setpoint to follow the rule set in Step1.



Required reaction timing is >1s: compatible with EV – EVSE communication

➢ Proposal: Architecture #2

Support to Frequency: Active Power Frequency response



In emergency situations, when the grid is close to collapse (out of nominal frequency range), active power generation has to be reduced quickly to support the grid.

2 solutions:

Each generator follows as accurately as possible the linear rule

- Applicable to big power unit with precise frequency measurement

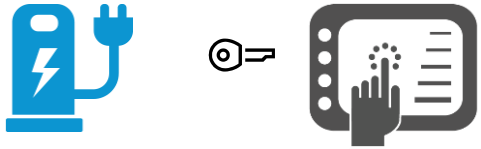
Each generator disconnects at random frequency in the given range

- Makes sense for dispersed µGenerators
- Doesn't need to precisely and dynamically regulate power
- Will use the decoupling relay and reconnect with the same rules

Applicable to V2G

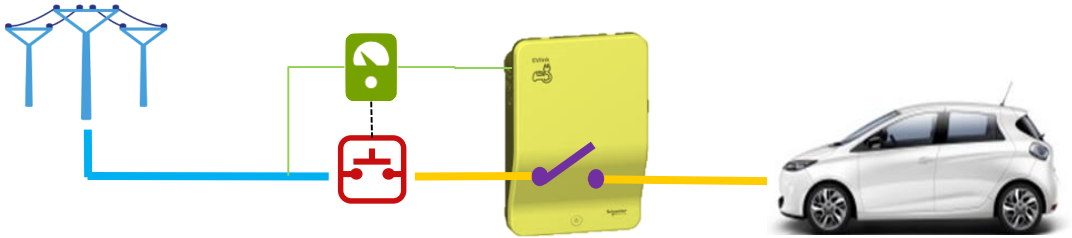
Support to Frequency: Active Power Frequency response

- Step 1 : EVSE installation



After installation, the electrician selects the right parameter set (frequency range) in the EVSE HMI with the DSO approval

- Step 2 : if the frequency reaches the defined random threshold, the interface switch is opened: reuse interface protection



Function allocation: focus on support to voltage and frequency

Function	Architecture
Support to voltage *Reactive power*	#2
Support to frequency *Active Power*	#2

- EVSE measures / calculates
- EVSE sends continuously setpoint
- BOBC applies power conversion

Grid Codes overview

Grid codes Functions	Reg 2016/631	EN50438	EN50549-1	ENEDIS-NOI-RES_13E	VDE AR N 4105	EREC G83/2	EREC G59/3	Rule 21
	avr-16	nov-13	**janv-19**	juil-16	août-11	déc-12	août-14	sept-17
	>800W	<16A	>800W			<16A	>16A	all
interface protection		x	x	x	x	x	x	x
Voltage Immunity			x					x
Frequency Immunity	x	x	x				x	x
ROCOF immunity	X		x			x	x	
support to voltage		Fixed cos phi, cosPhi(P), Q(V)	All modes		Fixed cos phi, cosPhi(P)			Fixed CosPhi, Q(V)
support to frequency	x	x	x		x			
Remote trip / setpoint	x		x		x			in 2018
Ramp rates and soft start	x					x		x

Note : requirements applicable to the scope of V2G-AC : below 32A three-phase

Summary of functions allocation

EVSE / Installation

EV bidirectional on-board-charger

- Store all grid code local parameters
- Decoupling protection
- Measure / calculate reactive power compensation setpoint
- 4 quadrant power conversion
- Active islanding detection
- Enhanced Immunity to voltage / frequency

Next Steps

- Continue standardization work: ISO / IEC / CENELEC
- Experimentations on fleets of vehicles in Europe

Thanks