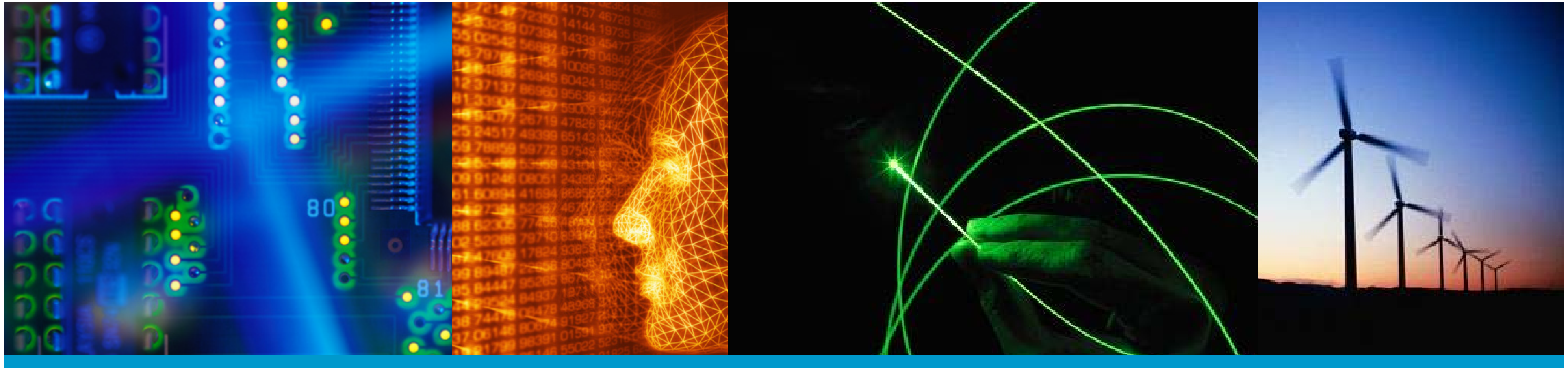

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Mobilidade Eléctrica e Redes Eléctricas Inteligentes

2011 **Set**

J. A. Peças Lopes
FEUP & INESC Porto
jpl@fe.up.pt

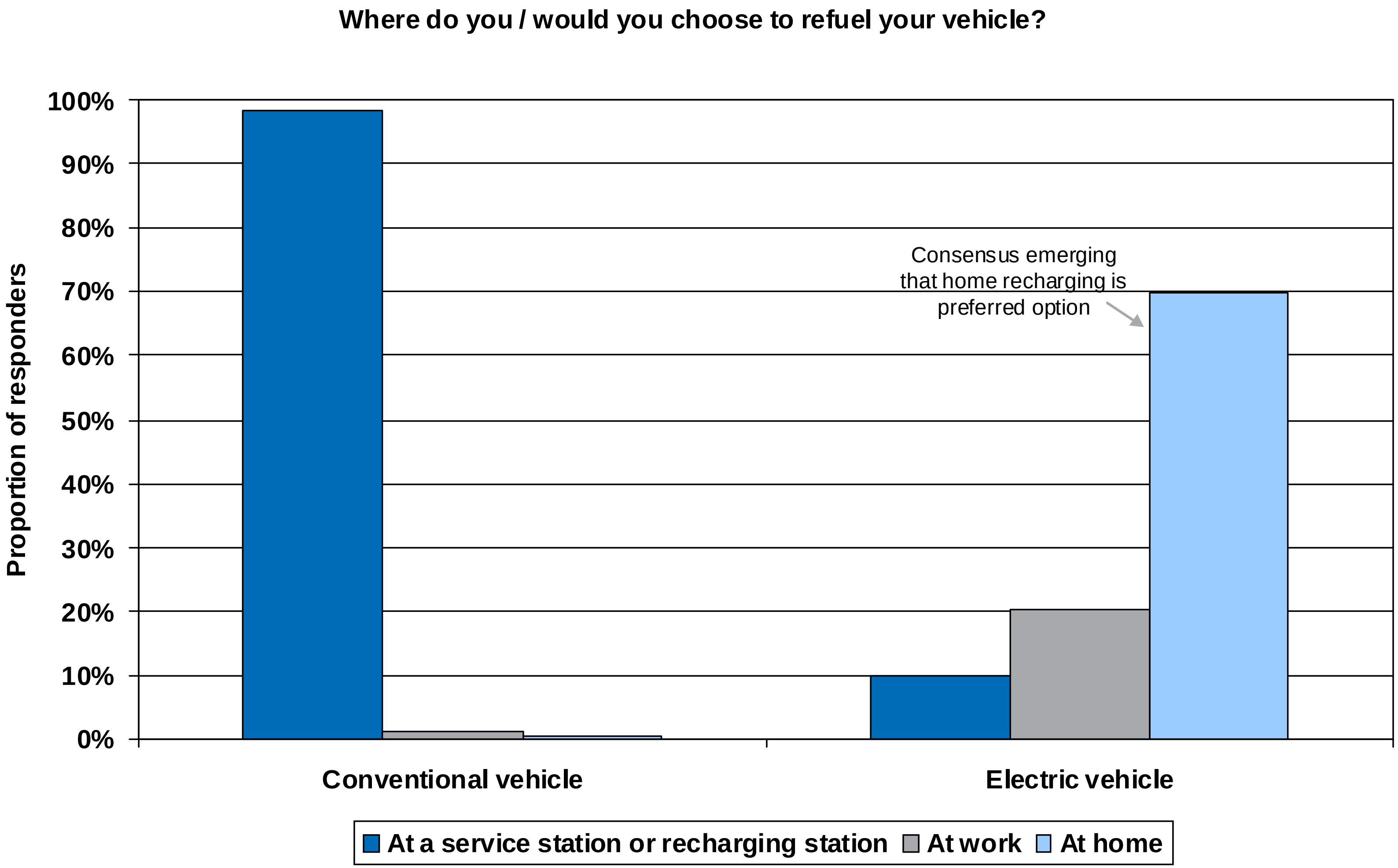
How to address EV and demand response for Power Systems operation

Steps to be performed:

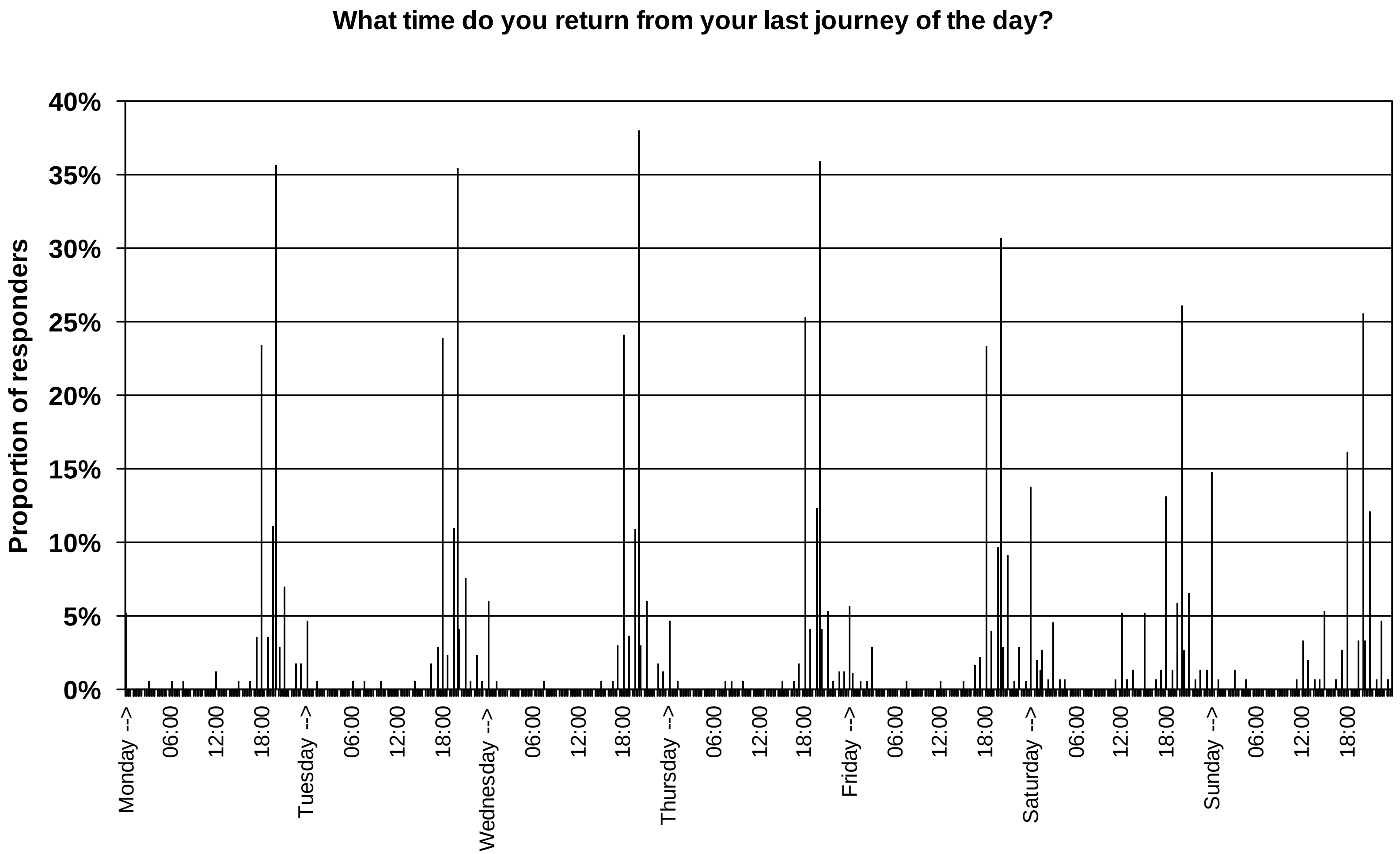
1. Need to understand the behavior of consumer's response and EV drivers → Surveys
2. Impacts in Power System operation and planning:
   - Steady state operation
   - Dynamic behaviour
   - Generation reserve needs
   - Electricity markets

   → Specific simulation tools capable to incorporate EV drivers behaviours and demand response → new management and control concepts.
3. Definition of management solutions with implications on EV battery charging modes and load management
4. Analysis of the operation of the system with the presence of RES + EV

Understanding EV driver behaviors':
RESULTS FROM THE MERGE PROJECT:
REFUELLING AND RECHARGING LOCATION PREFERENCES



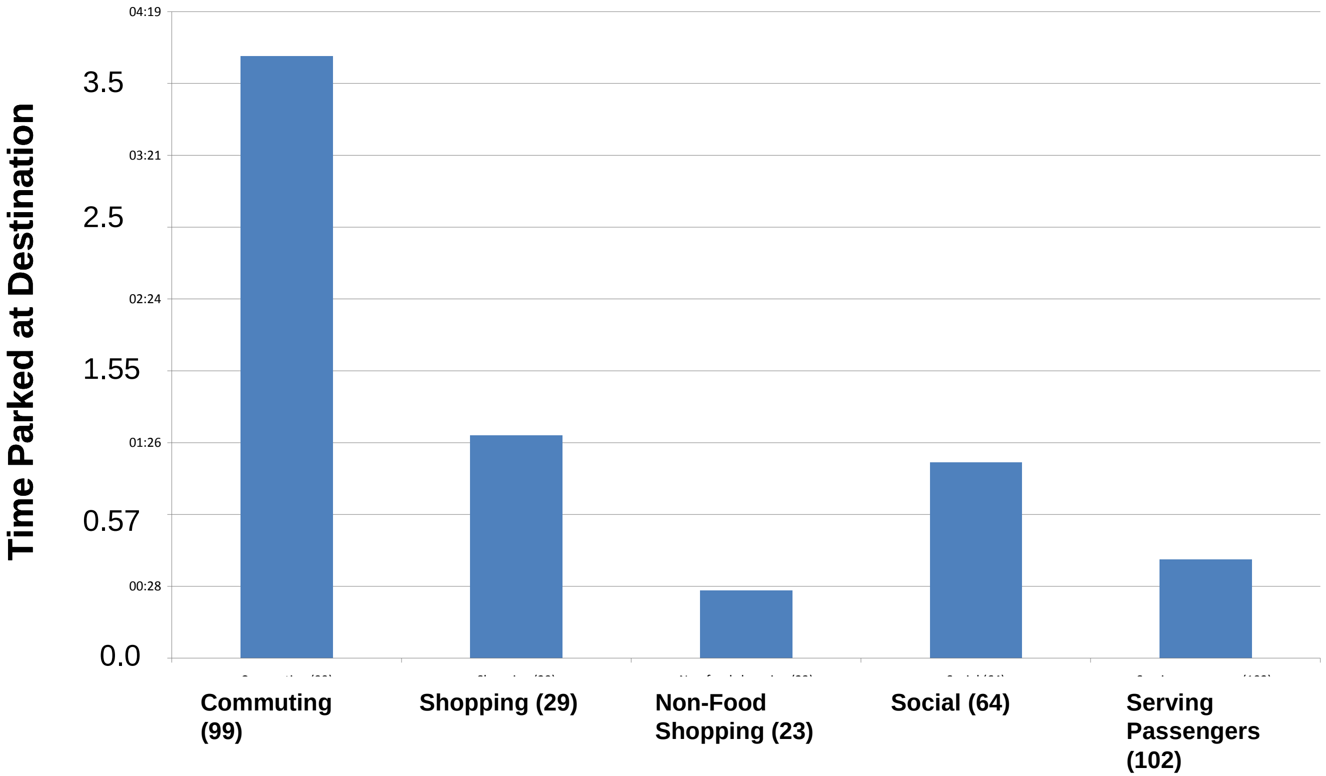
Understanding EV driver behaviors':
RESULTS FROM THE MERGE PROJECT:
PROFILE OF TIME OF RETURN FROM LAST JOURNEY OF THE DAY, PORTUGAL



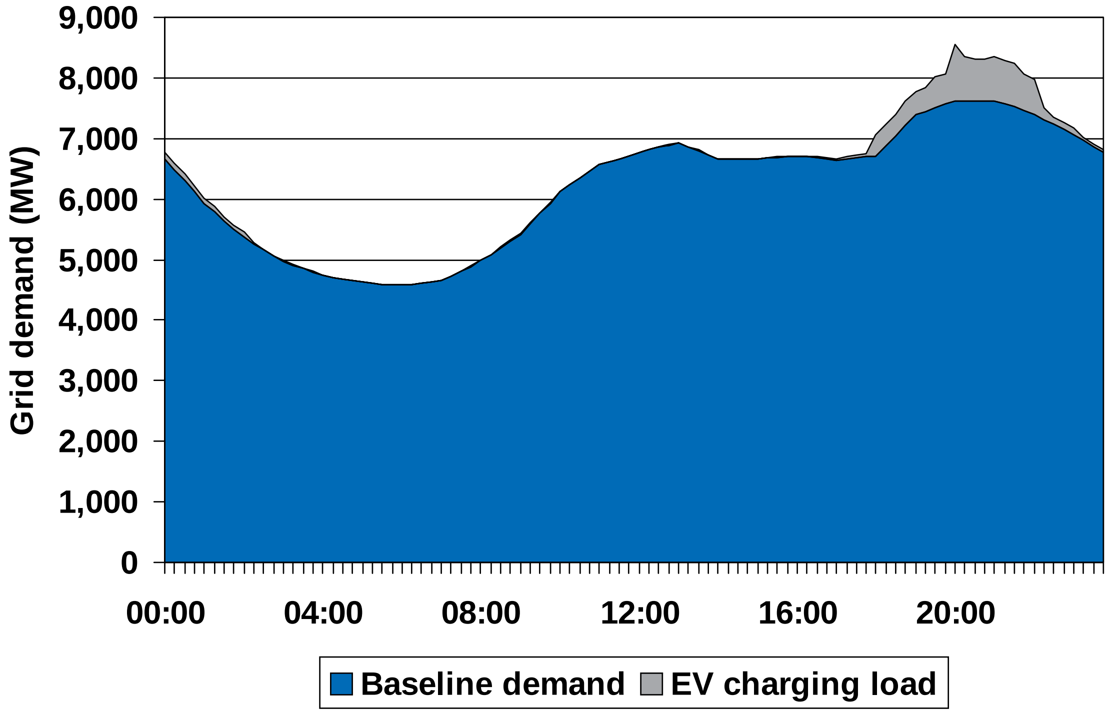
Understanding EV driver behaviors':

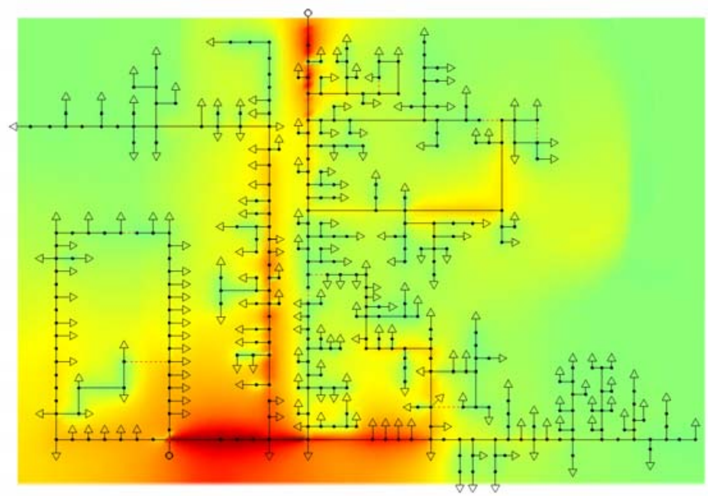
RESULTS FROM THE MERGE PROJECT:

Time Parking at destination



EFFECT OF EV DUMB CHARGING SCENARIO ON PORTUGAL'S ELECTRICITY DEMAND (10% EV)



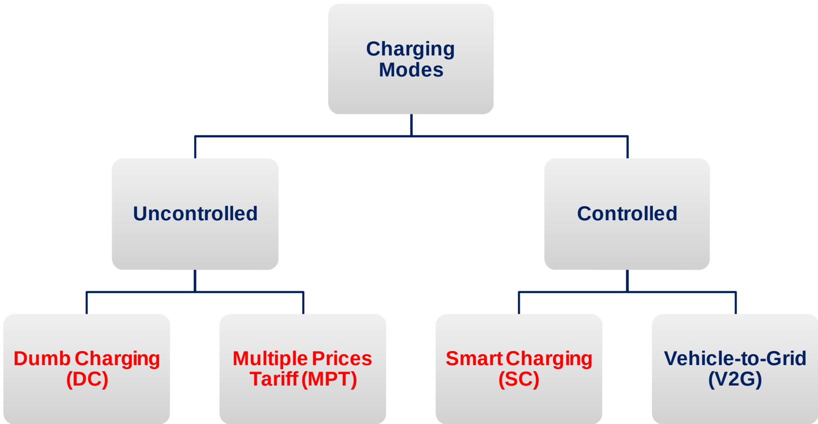


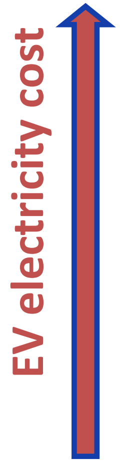
SMART CHARGING IS REQUIRED

Conceptual Framework for EV Integration Into Electric Power Systems

Possible EV charging approaches and drivers' behaviours

- Charging approaches:



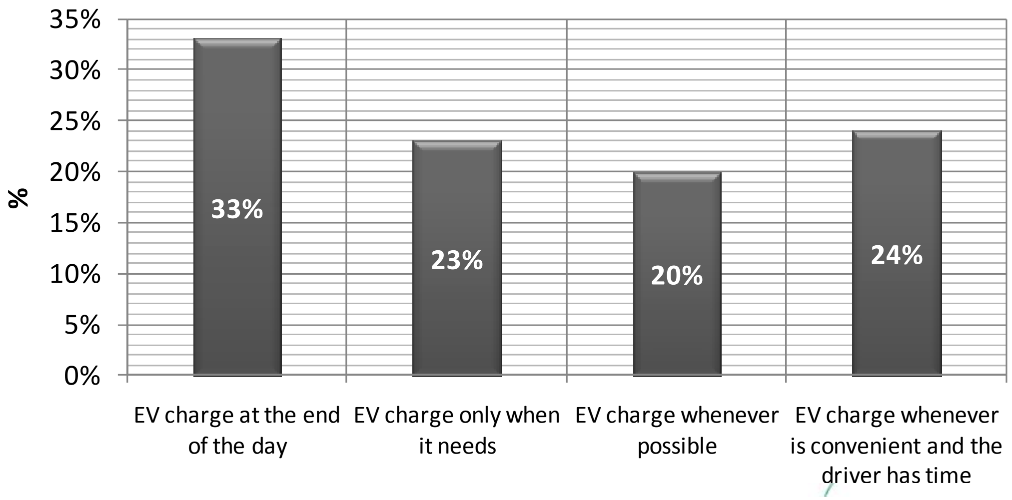


Dumb Charging - EV owners are free to charge their vehicles whenever they want; electricity price is constant along the day.

Multiple Prices Tariff - EV owners are free to charge their vehicles whenever they want; electricity price is not constant along the day.

Smart Charging - envisions an active management system, where there are two hierarchical control structures, one headed by an Aggregator and other by the DSO, that control EV charging according to Aggregator's market negotiations or according to the grid's needs.

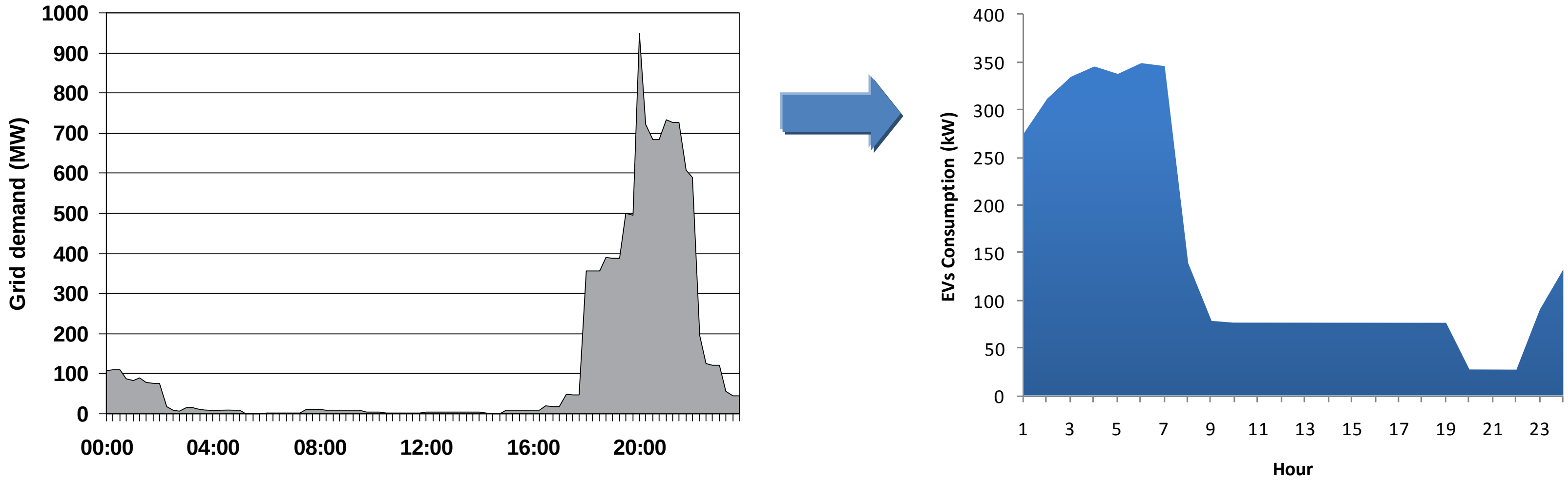
- Drivers´ behaviours:



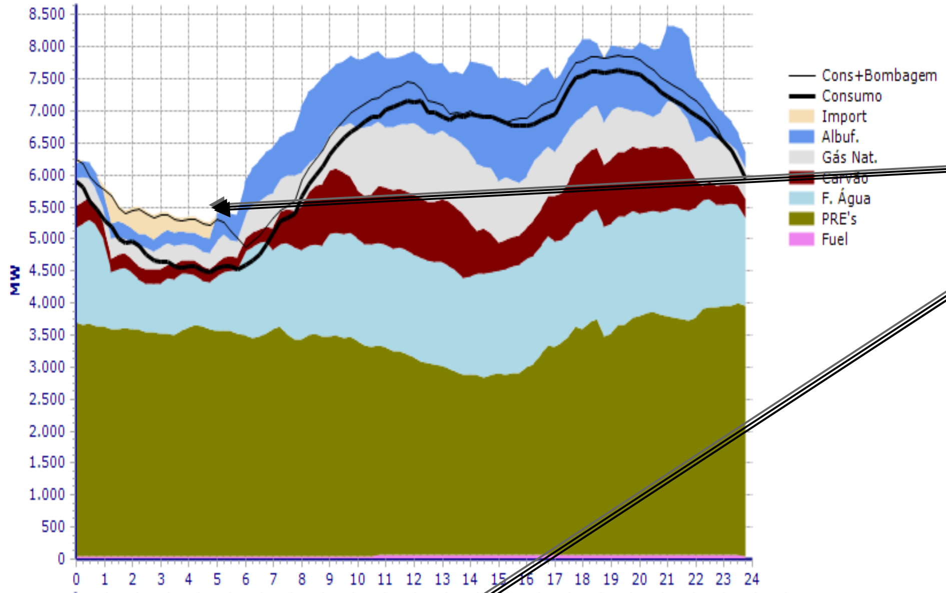
Behaviours defined according to the findings of a survey made within the framework of the MERGE project

EV CONTROLLED CHARGING

- Developing the Smart Charging concept → moving charging to valey hours (night periods)

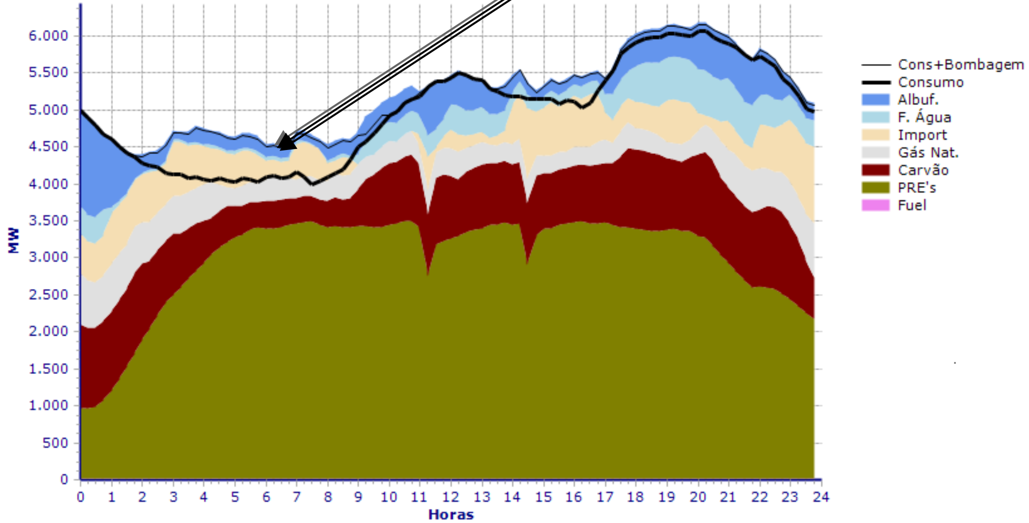


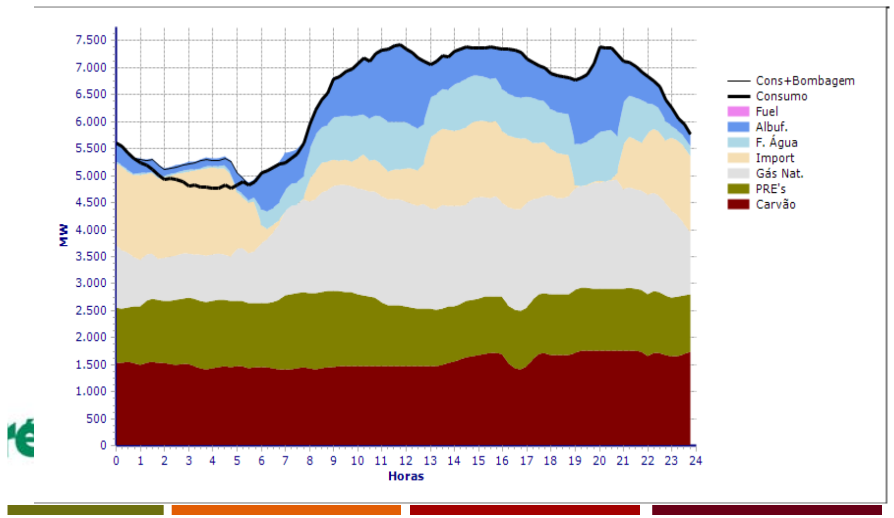
The Variability of the Renewable Generation



Surplus of renewable generation

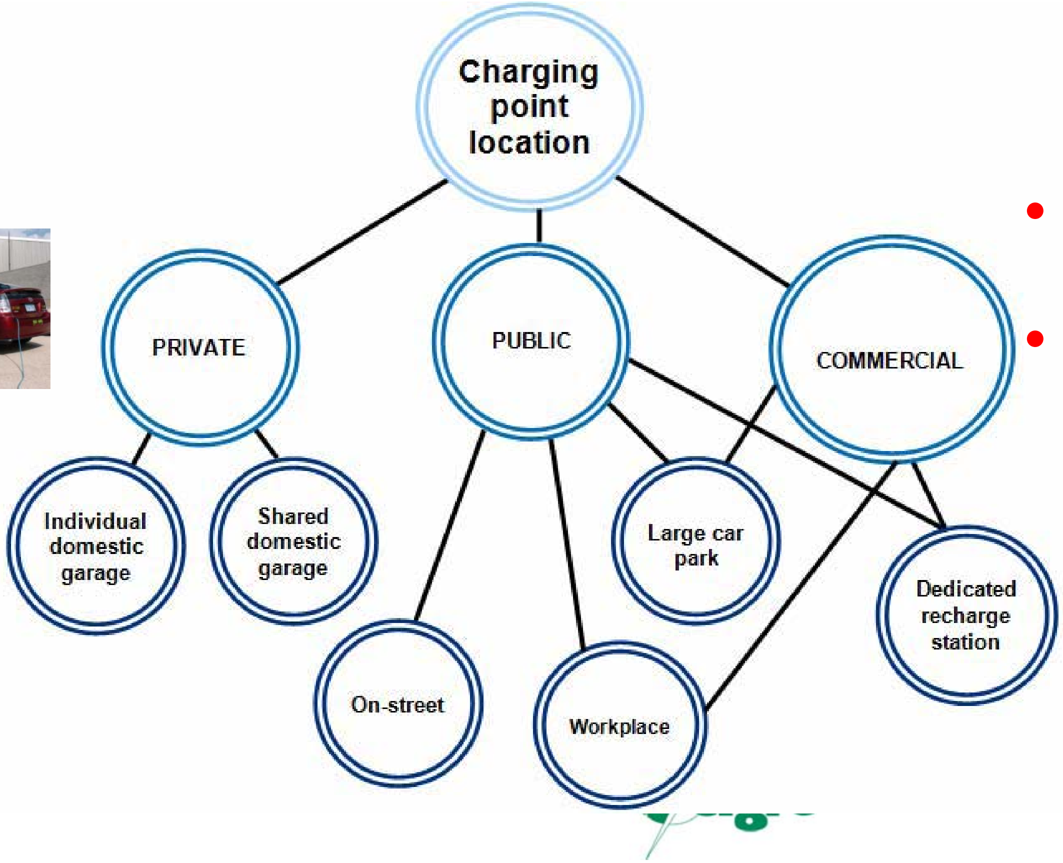
The availability of RES → EV charging





Conceptual Framework for EV Integration Into Electric Power Systems - *Type of charging points*

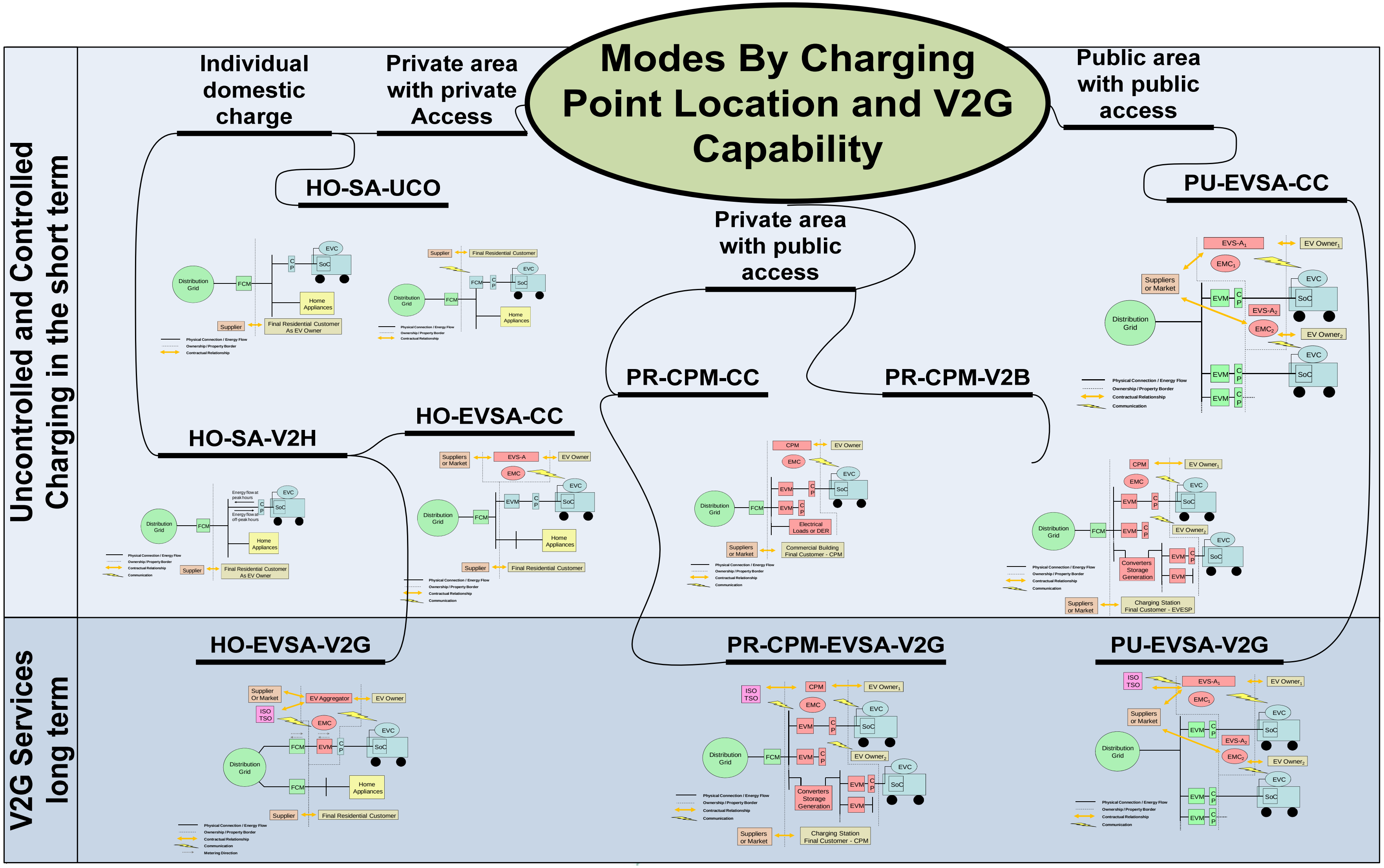
Charging points can present different characteristics according to the location



- Dumb charging
- Controlled charging

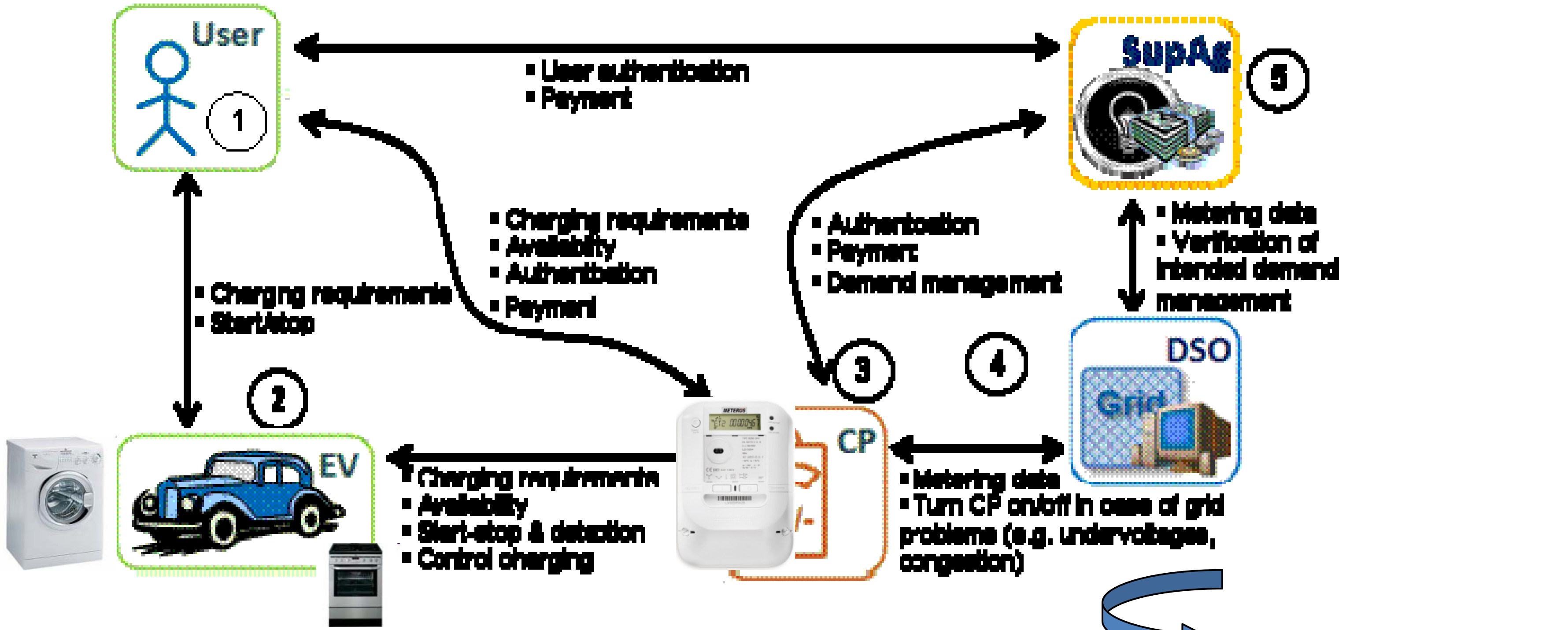
Fast Charging

EV Charging modes overview – regulatory approach



Overview of the different information flows

An ICT model was developed, identifying the involved parties and the associated information flows.



The MERGE control concept

- **A two level hierarchical control approach needs to be adopted:**
  - Local control housed at the EV grid interface, responding locally to grid frequency changes and voltage drops;
  - Upper control level designed to deal with:
    - "short-term programmed" charging to deal with branch congestion, voltage drops
    - Delivery of reserves (secondary frequency control);
    - Adjustments in charging according to the availability of power resources (renewable sources).

Surplus of Renewable Energy (valley hours) has now clients!

EV Voltage / Frequency support modes

- Voltage Control
  - Local Control
  - Coordinated Control
- Frequency Control
  - Primary Control (local control)
  - Secondary Control

Communication infrastructure

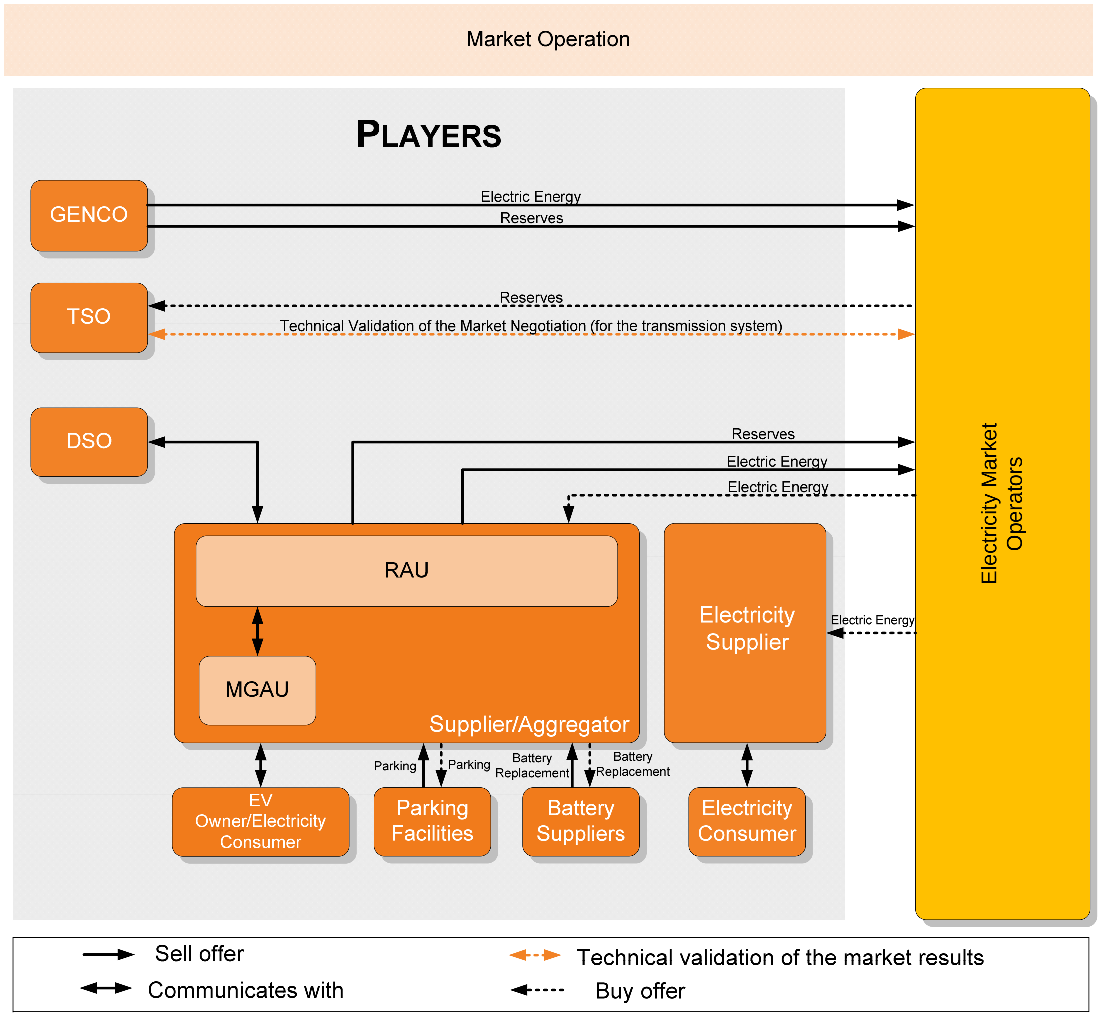
Local control to be implemeted in a similar way to SAE 1772

Active rectifiers or should be adopted to interface EV with the grid.

Conceptual Framework For EV Integration

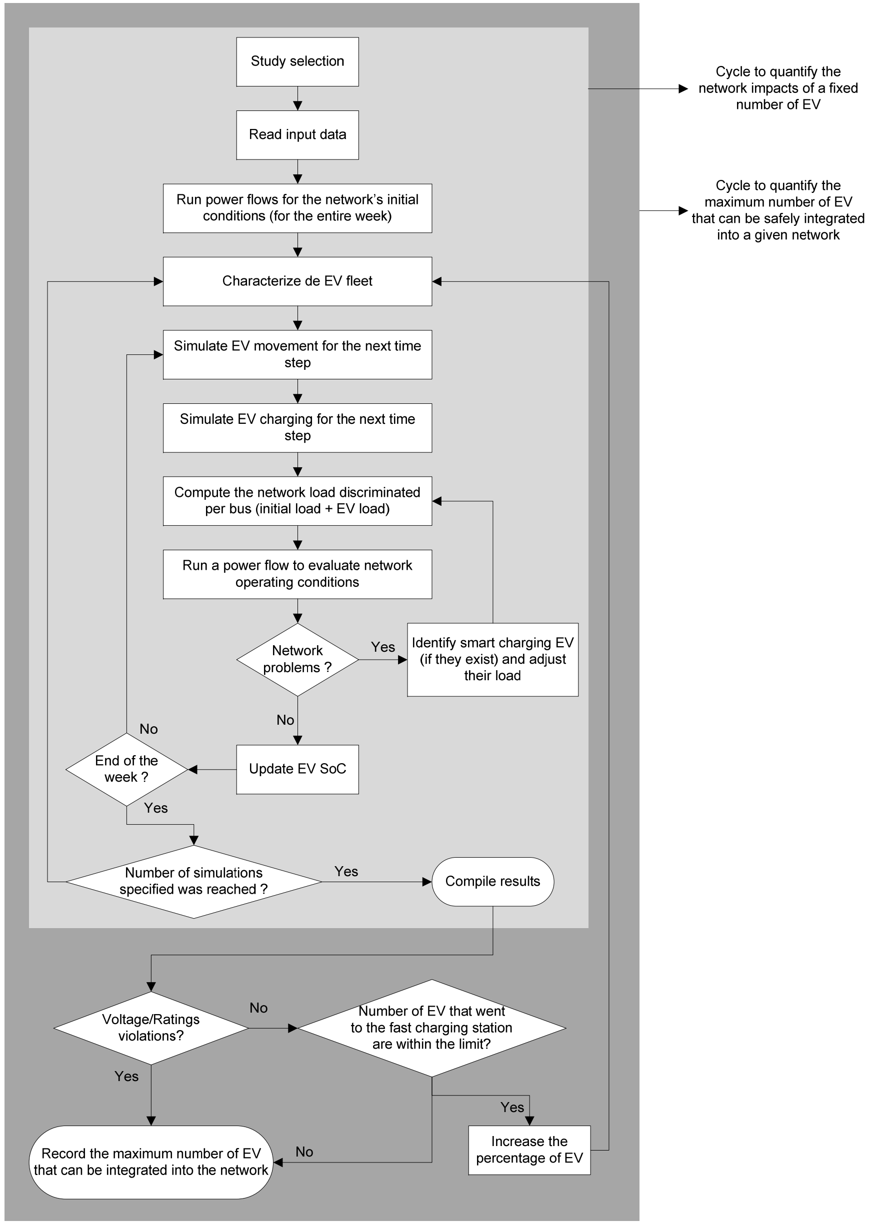
- EV must be an active element within the power system

- The Upper Level control requires interactions with:
  - **An Aggregating** entity to allow:
    - Reserve management
    - Market negotiation



PSS/E STEADY STATE SIMULATION TOOL

TOOL MAIN OBJECTIVE: compute the maximum number of EV that can be integrated in a given distribution network with the three charging approaches. The maximum EV integration is attained when a network technical restrictions occurs.



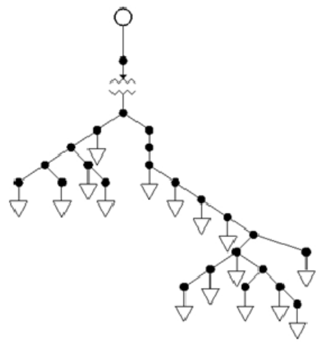
GRID INDEXES EVALUATED:

- **Total Load (Grid + EV)**
- **Minimum and Maximum Voltages**
- **Maximum Line Rating**
- **Peak Power**
- **Losses**

Evaluation of EV Impacts in Distribution Networks – 1

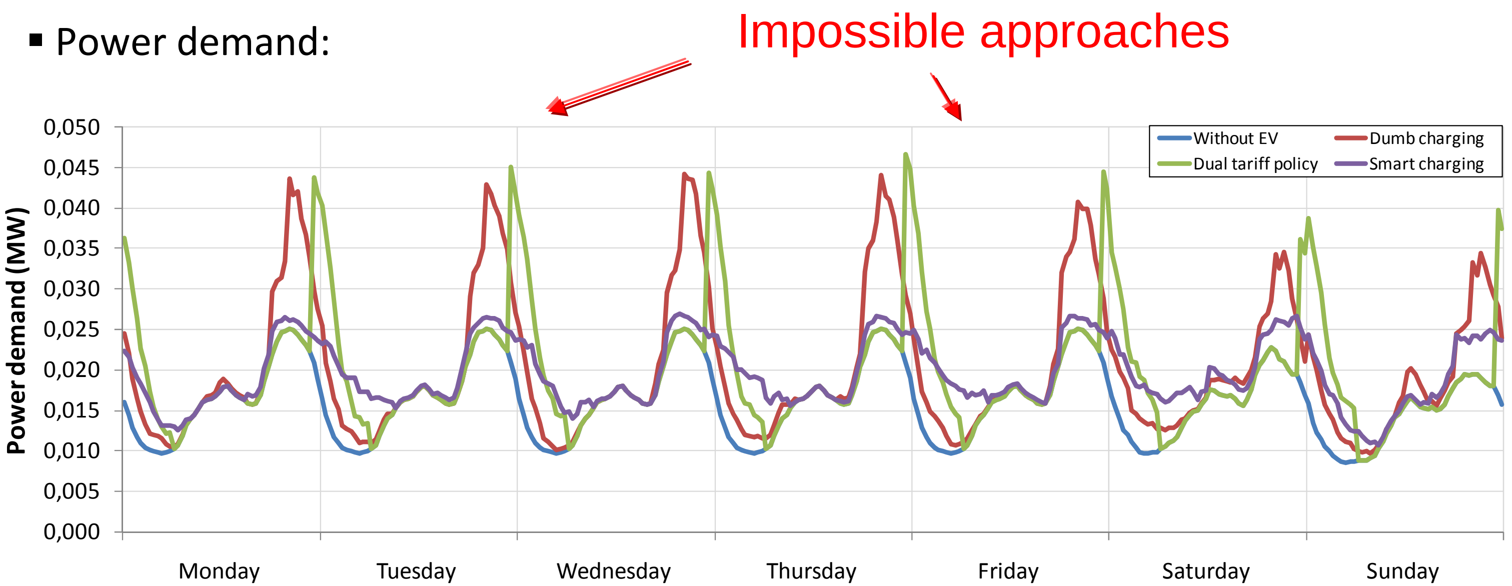
Case study: typical Portuguese LV grid (residential area)

- Data and assumptions:
  - Peak load – 25.1 kW
  - Annual energy consumption – 111 MWh
  - Vehicles in the network – 30
  - 30% of the fleet of vehicles are electric
  - Period of lower energy price for Multiple Tariff Policy adherents – 23h to 6h



Single line diagram of the LV test network

- Results:
  - Power demand:

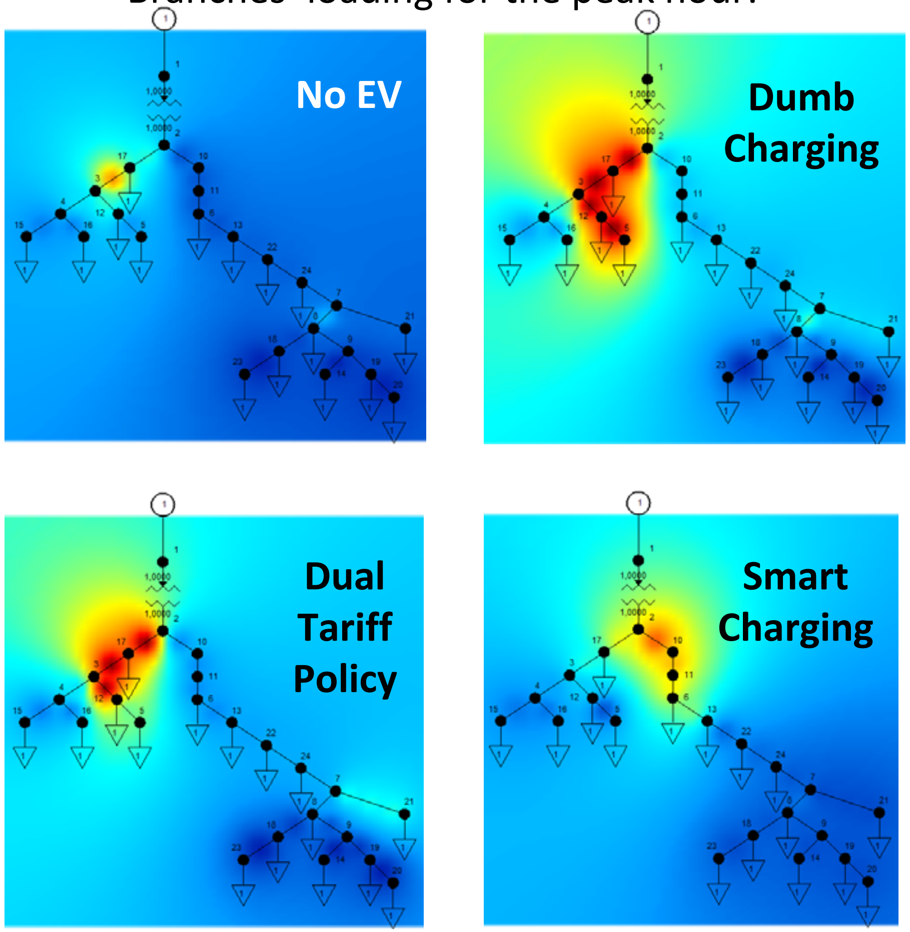


Evaluation of EV Impacts in Distribution Networks – 2

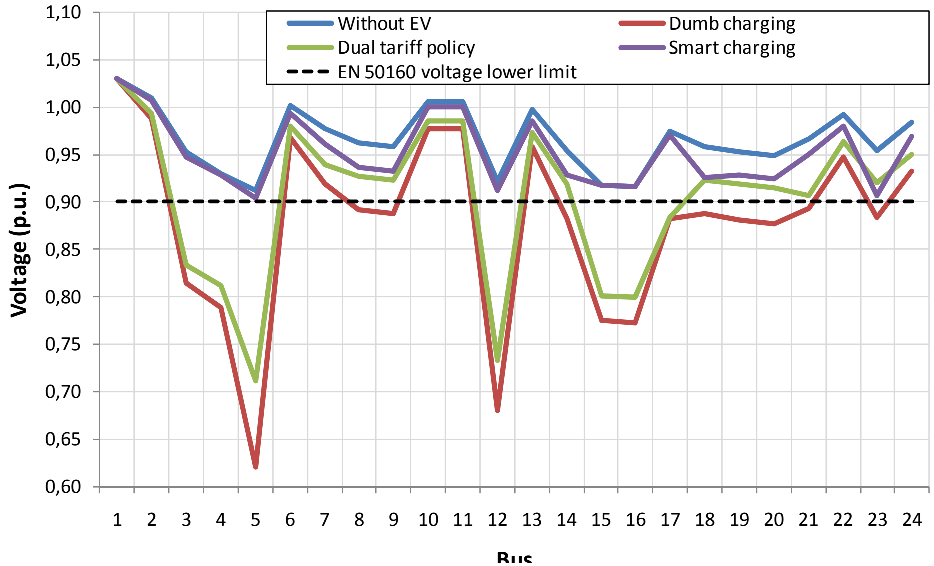
Case study: typical Portuguese LV grid (residential area)

➢ Results:

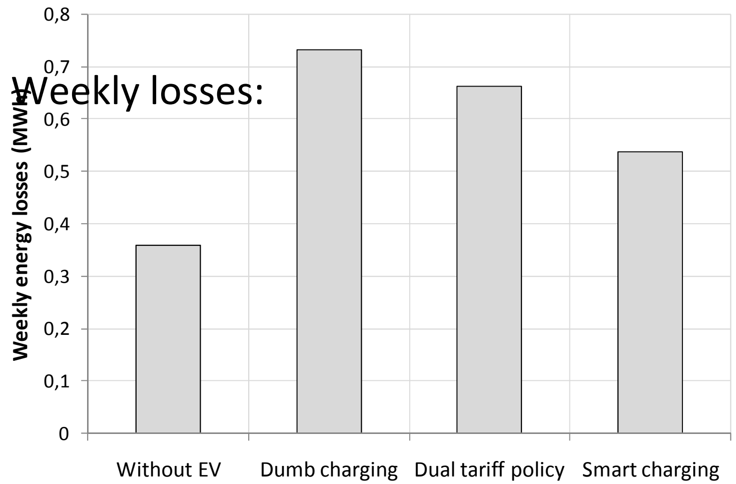
- Branches' loading for the peak hour:



- Voltage profiles for the peak hour:

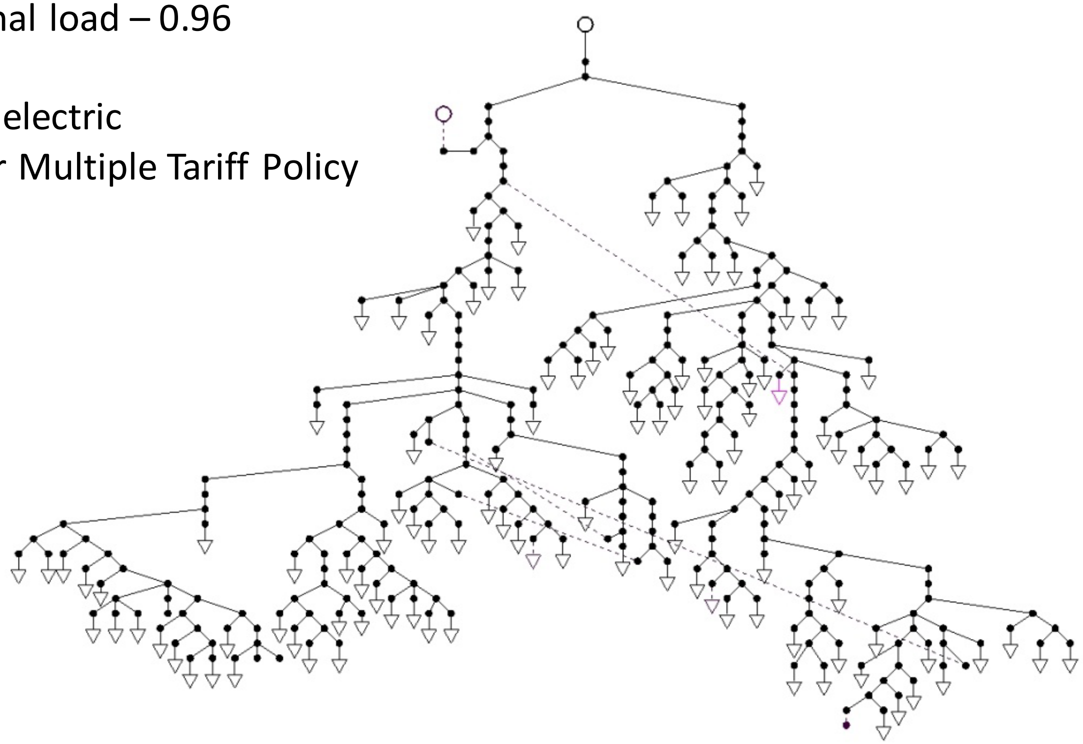


- Weekly losses:

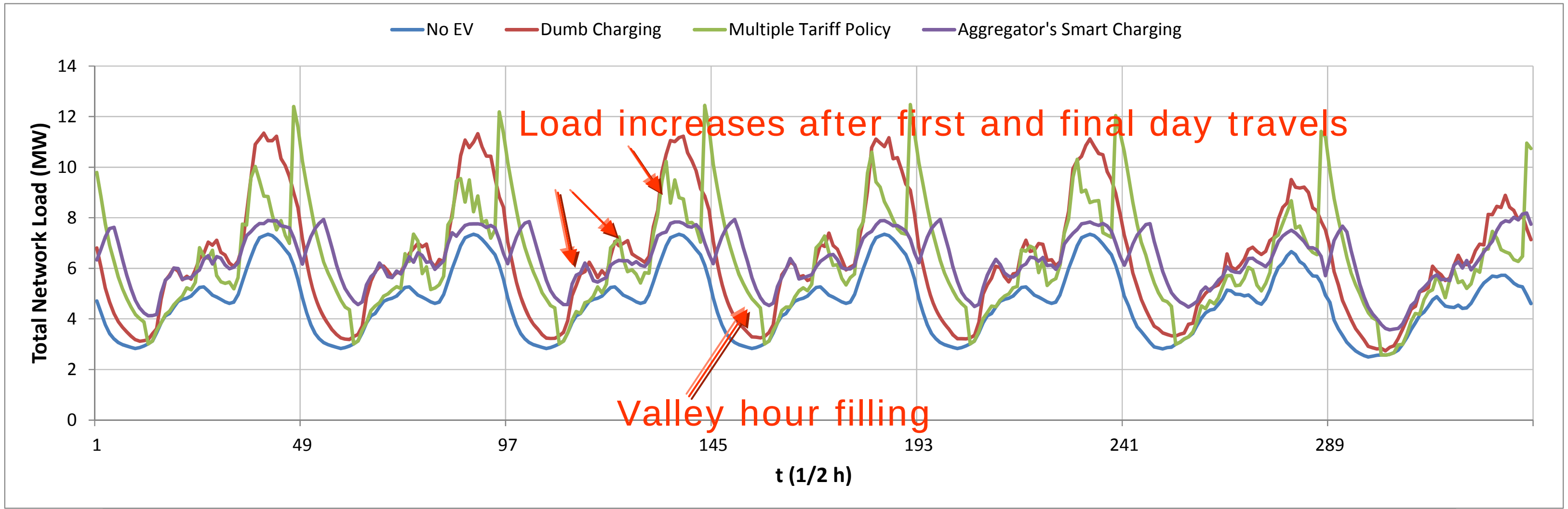


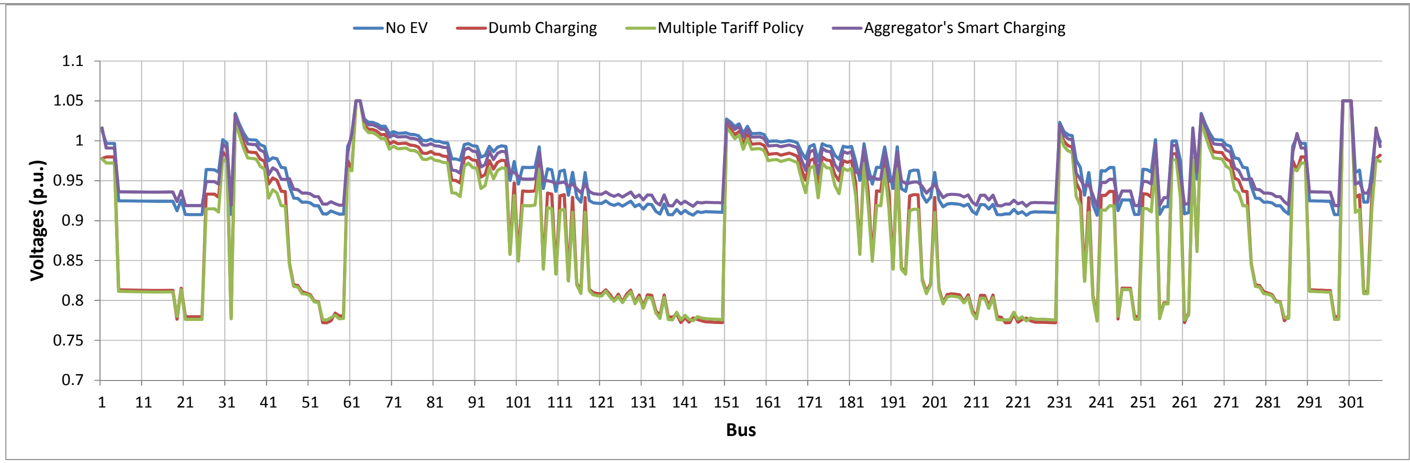
Evaluation of EV Impacts in Distribution Networks
Case study: typical Portuguese MV grid

- Data and assumptions:
  - Peak load – 7.3 MW
  - Annual energy consumption – 32 GWh
  - Power factor for the conventional load – 0.96
  - Vehicles in the network – 7035
  - 30% of the fleet of vehicles are electric
  - Period of lower energy price for Multiple Tariff Policy adherents – 23h to 6h



Evaluation of EV Impacts in Distribution Networks – Case study: typical Portuguese MV grid

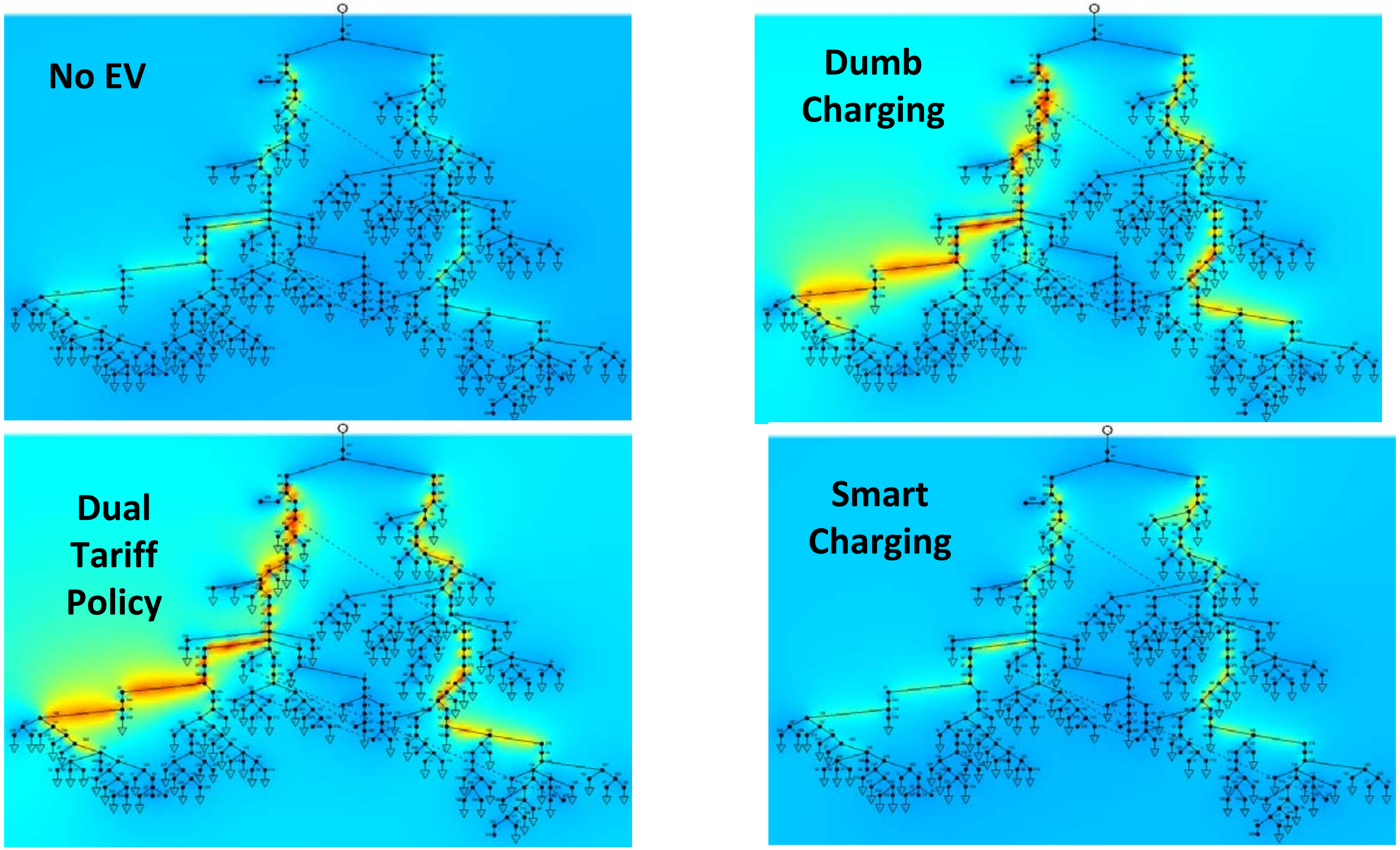




Evaluation of EV Impacts in Distribution Networks – Case study: typical Portuguese MV grid

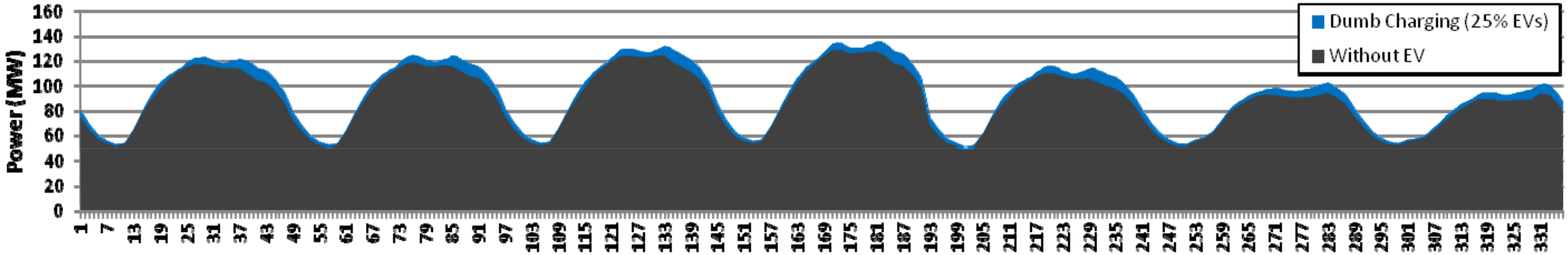
➢ Results:

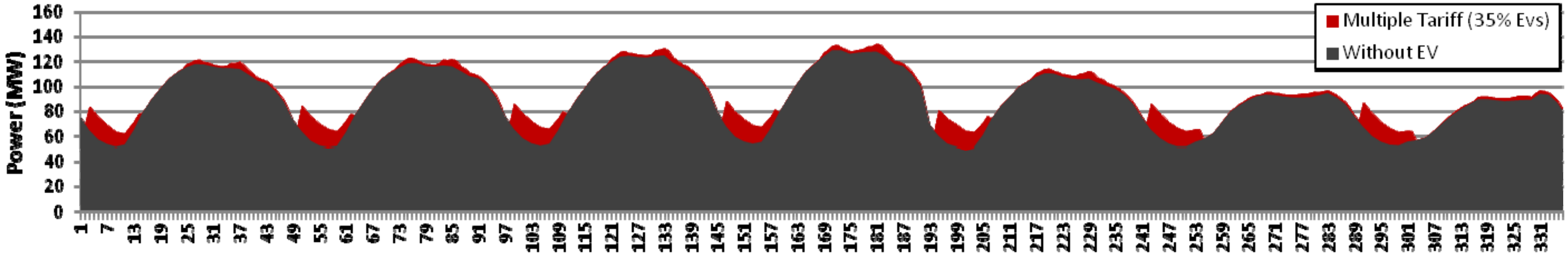
- Branches' loading for the peak hour:

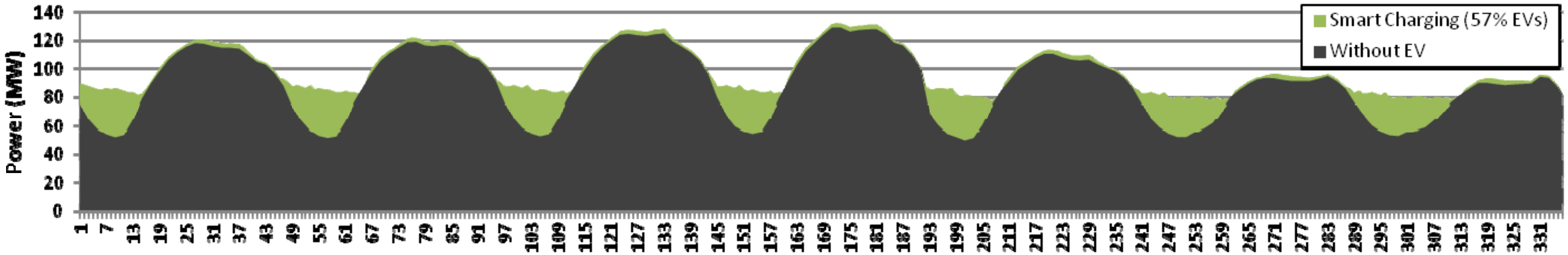


RESULTS OBTAINED
Old Network From an Urban Area

➢ **Network + EV Load – Comparison Between Charging Strategies:**

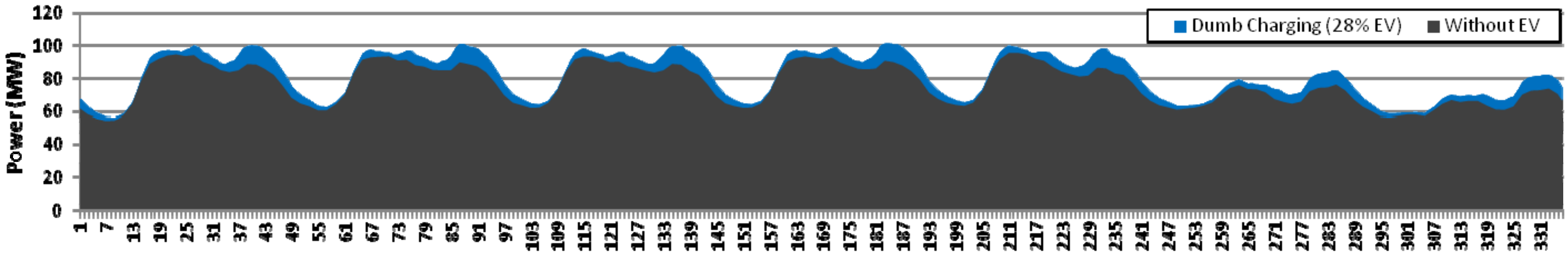


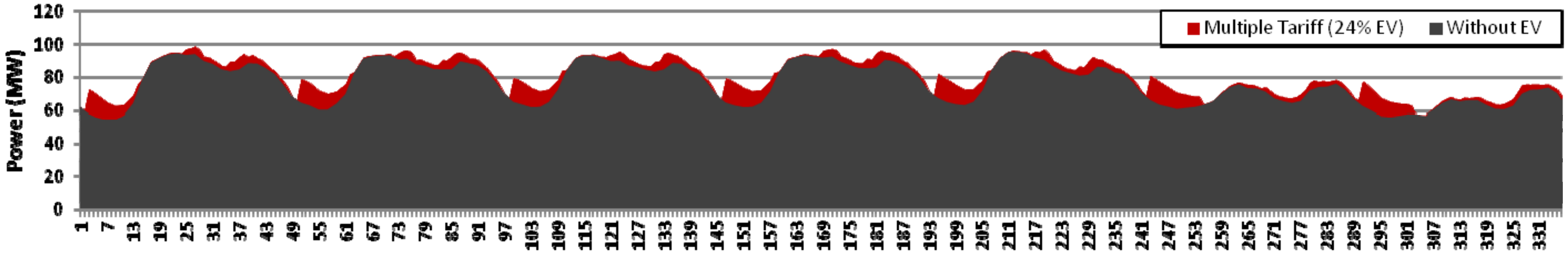


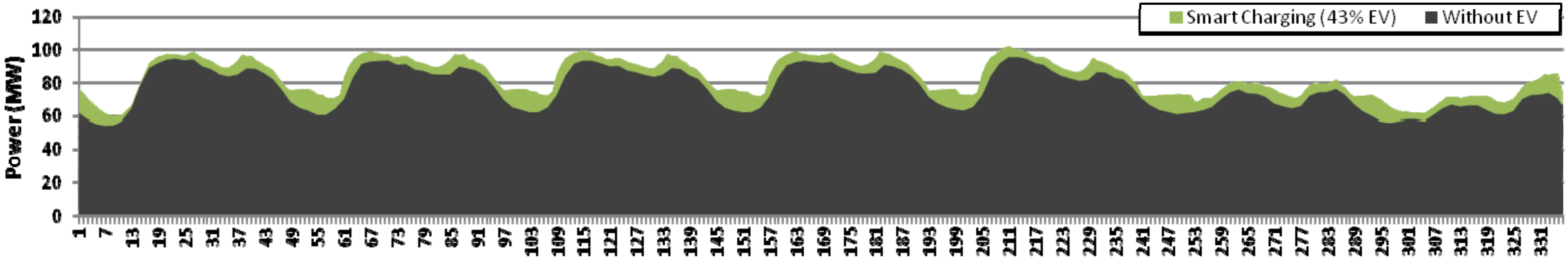


RESULTS OBTAINED
Residential Network

➢ **Network + EV Load – Comparison Between Charging Strategies:**





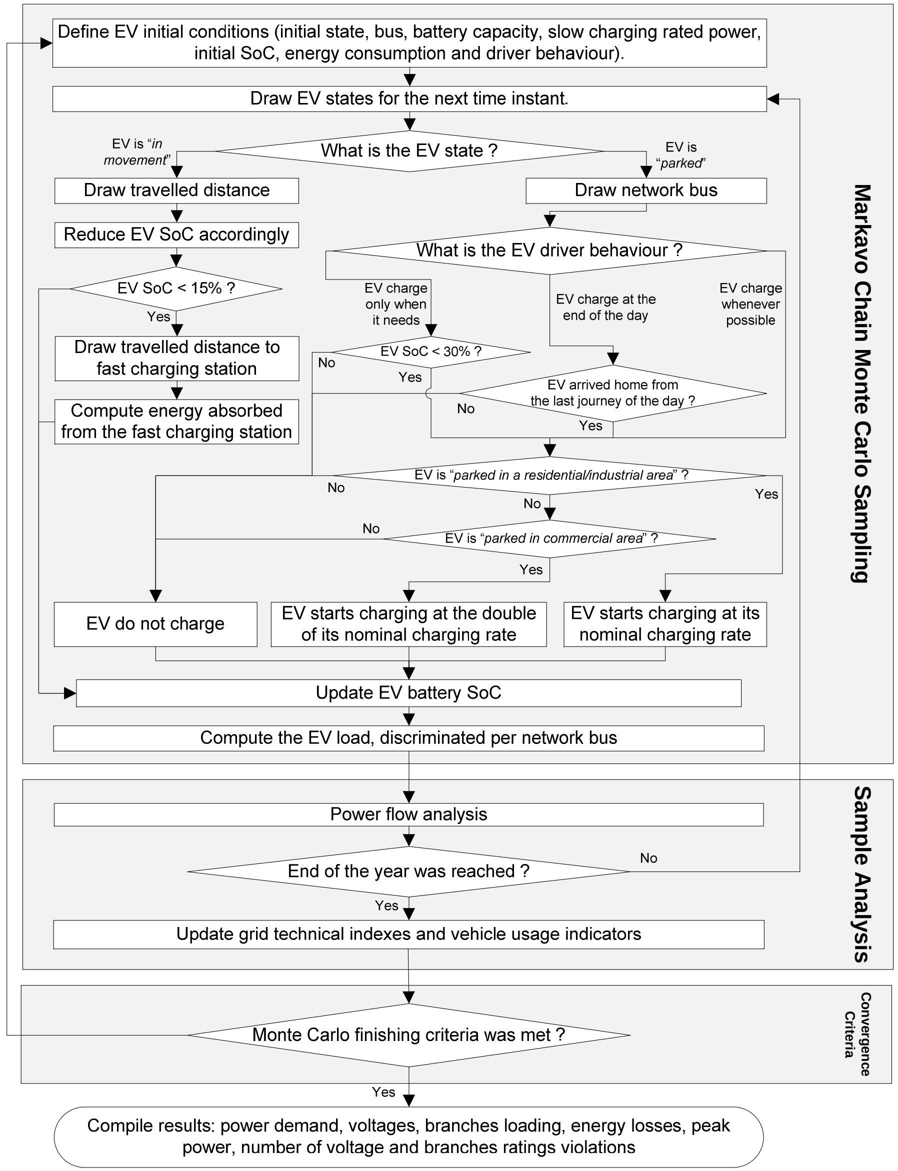


MONTE CARLO SIMULATION

- Sample analysis → Run a power flow for each time instant, using the PSS/E software, to gather relevant information
- Convergence criteria → 2 criteria were used:
  - number of iterations → minimum of 200 (means 200 years)
  - variances of the aggregated network load of each one of the 17520 time instants → variation of all the 17520 variances in the last 5 iterations must be lower than $1e^{-3}$

$$\Delta Variance = \left|Variance_h^t - Variance_{h-5}^t\right| < 1 \times 10^{-3}$$

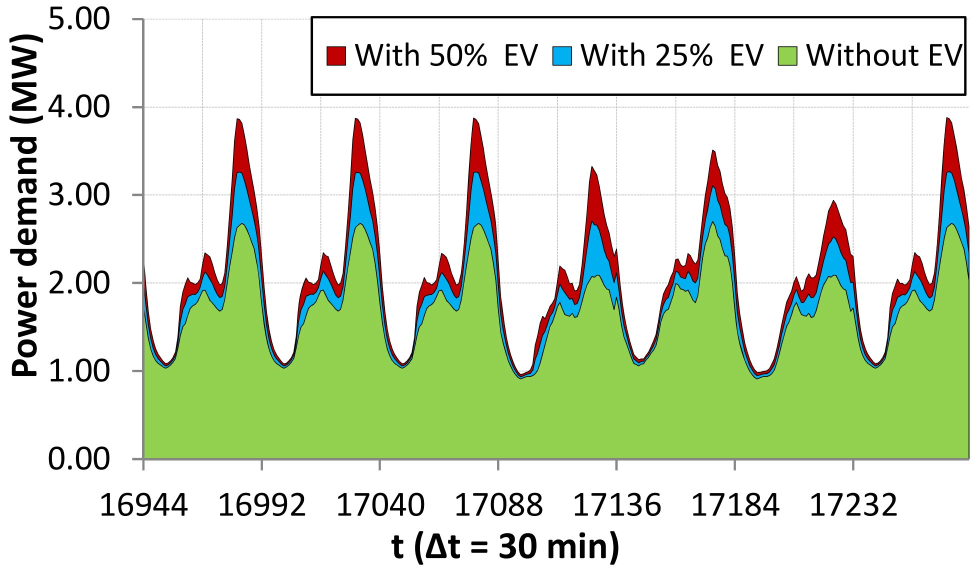
A gaussian distribution was adopted to calculate the travelled distances per journey



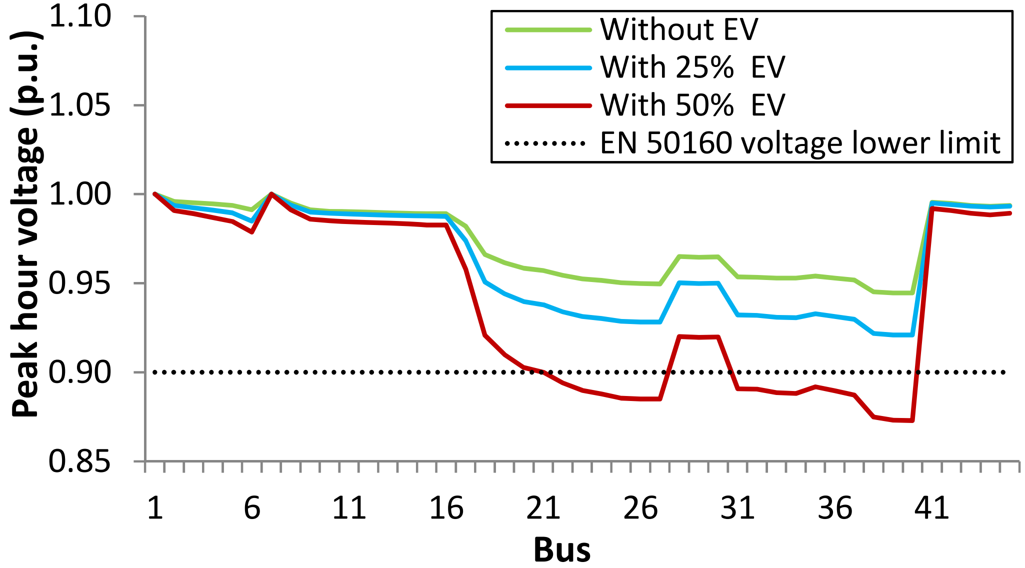
Monte Carlo algorithm flowchart

RESULTS

- **Power Demand**



- **Voltage profiles**

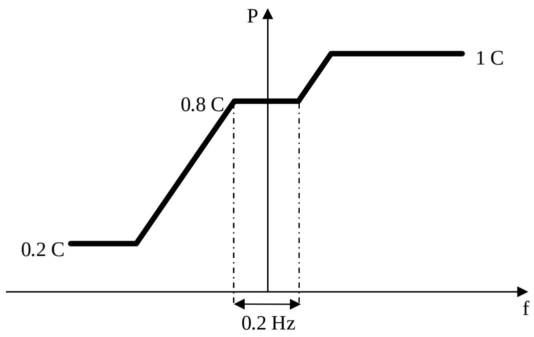


Reserve Provision with EV

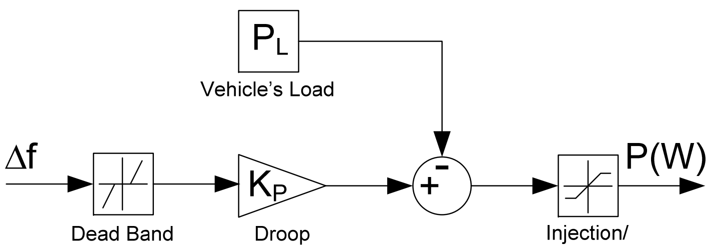
Local Droop Control and Automatic Generation Control (AGC)

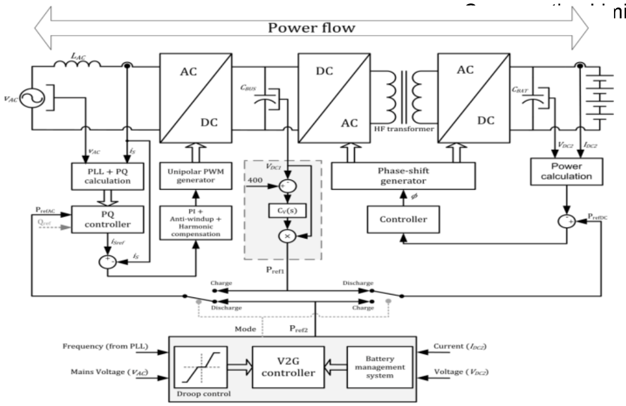
PRIMARY FREQUENCY CONTROL

Droop Control for EV



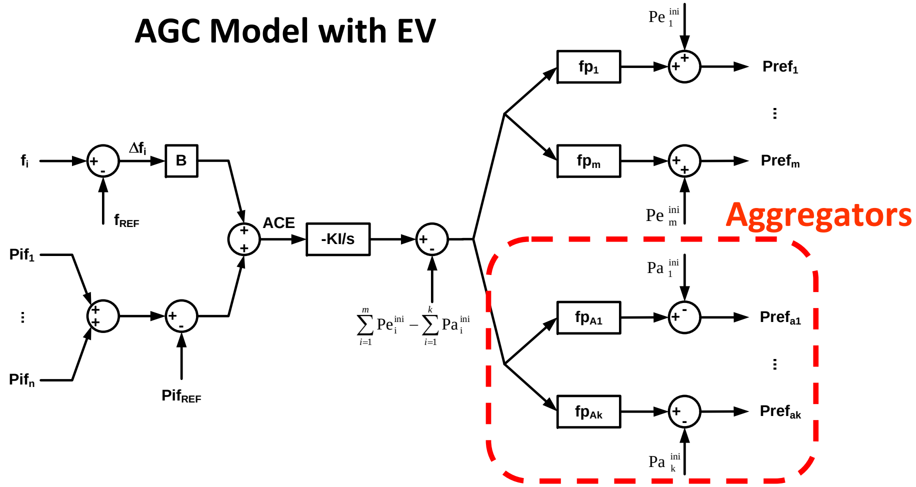
Control loop for EVs active power set-point





SECONDARY FREQUENCY CONTROL

AGC Model with EV



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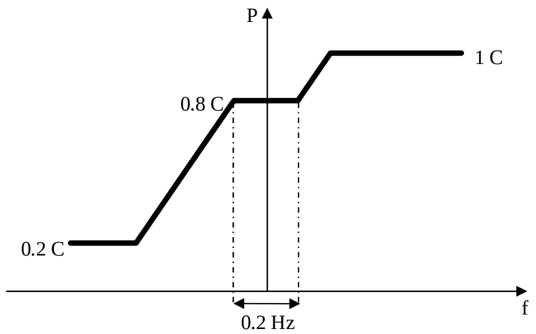
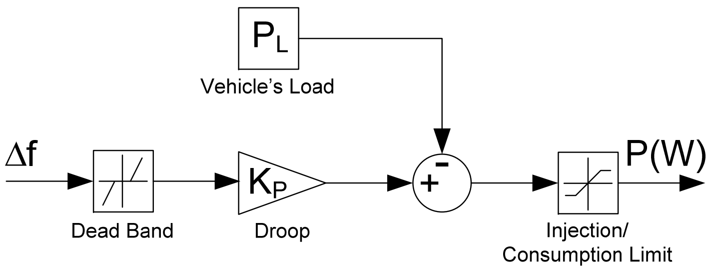
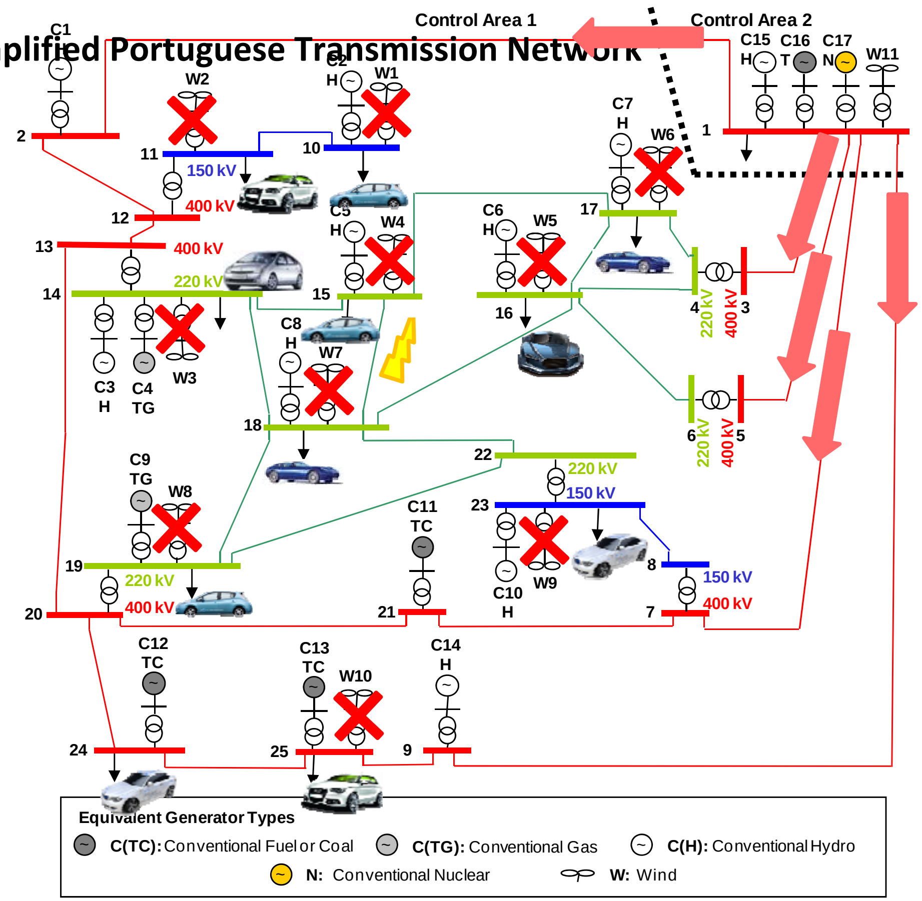


Control loop for EVs active power set-point



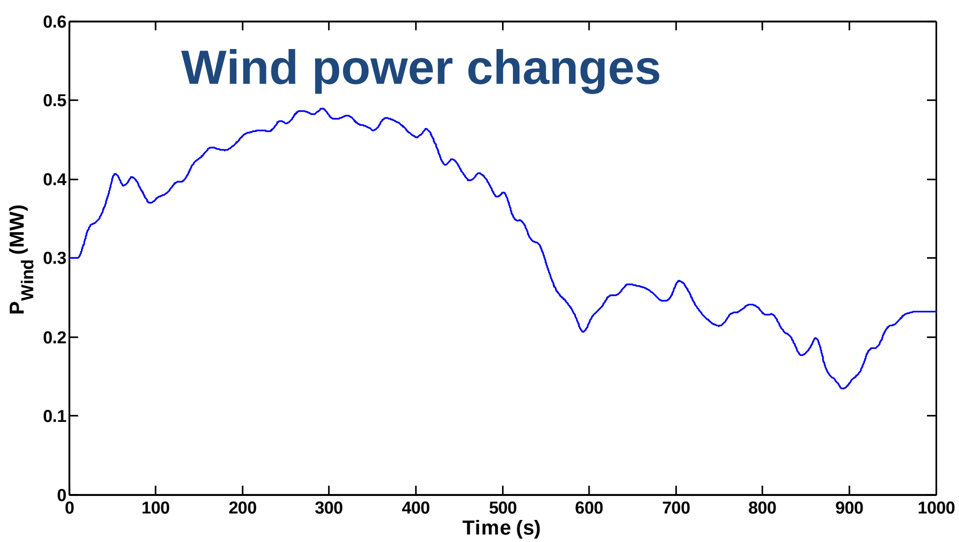
SECONDARY FREQUENCY CONTROL

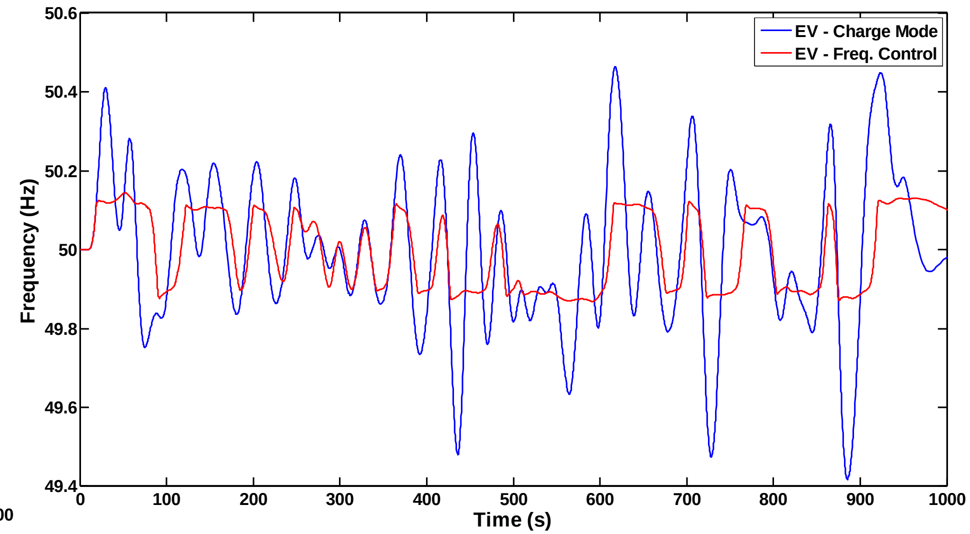


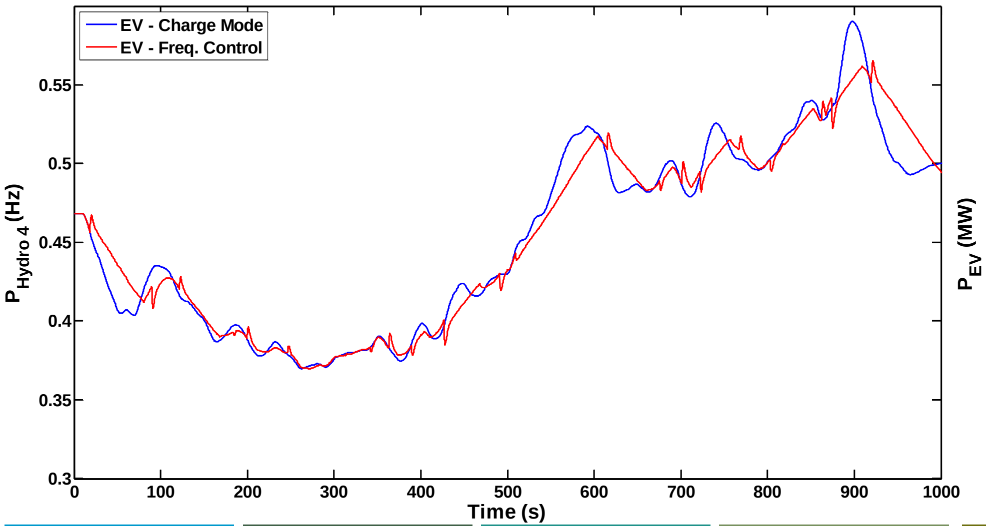
RES variability and grid disturbances that involve specific RES unit behavior will be easily accommodated through the response of flexible EV charging

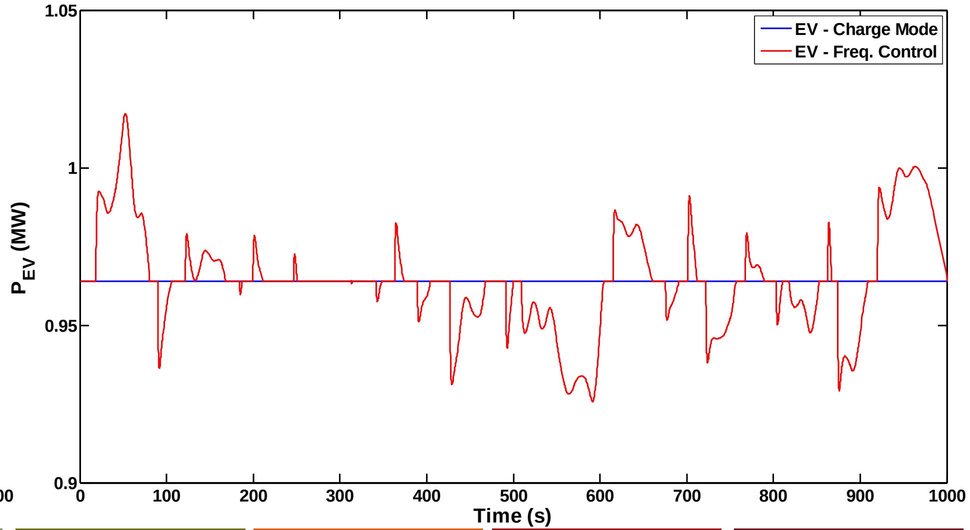
Reserve Primary Reserve
Frequency Control with EV

Particularly interesting in Islanded networks





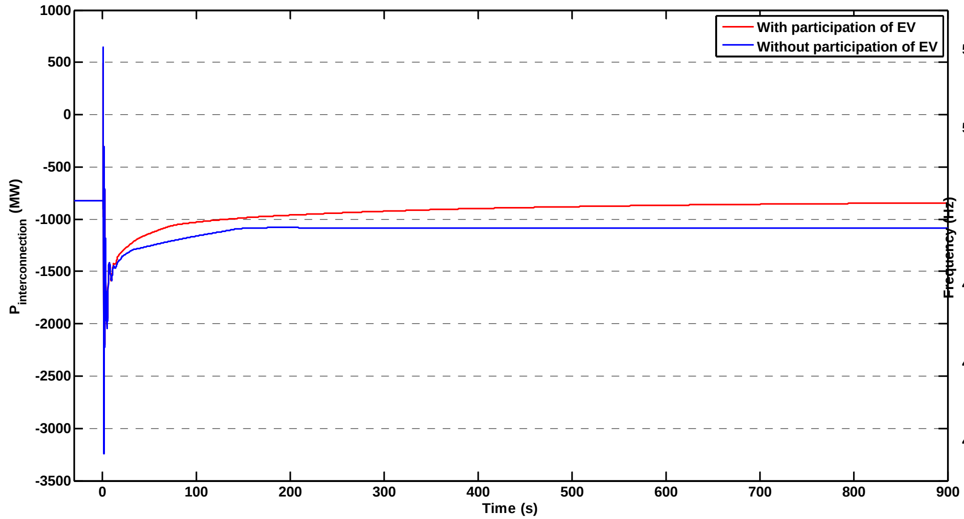


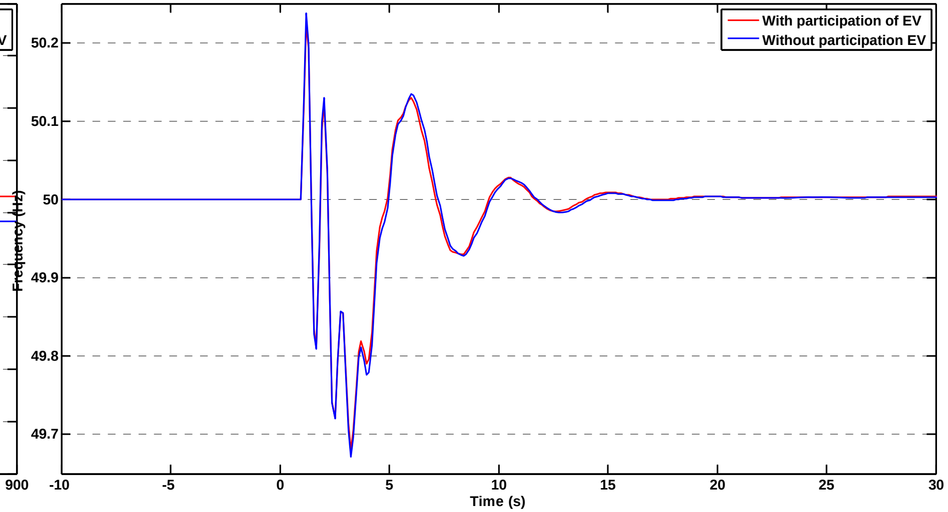


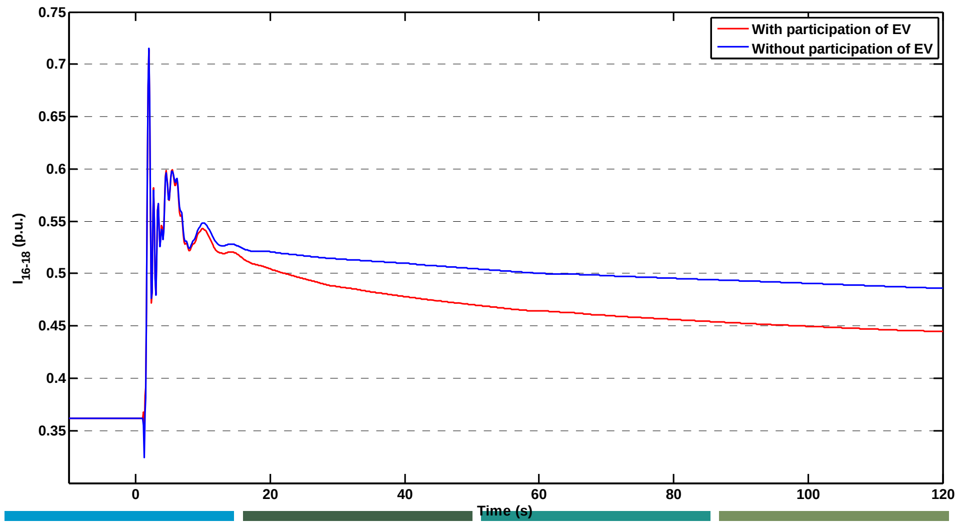
Secondary Reserve

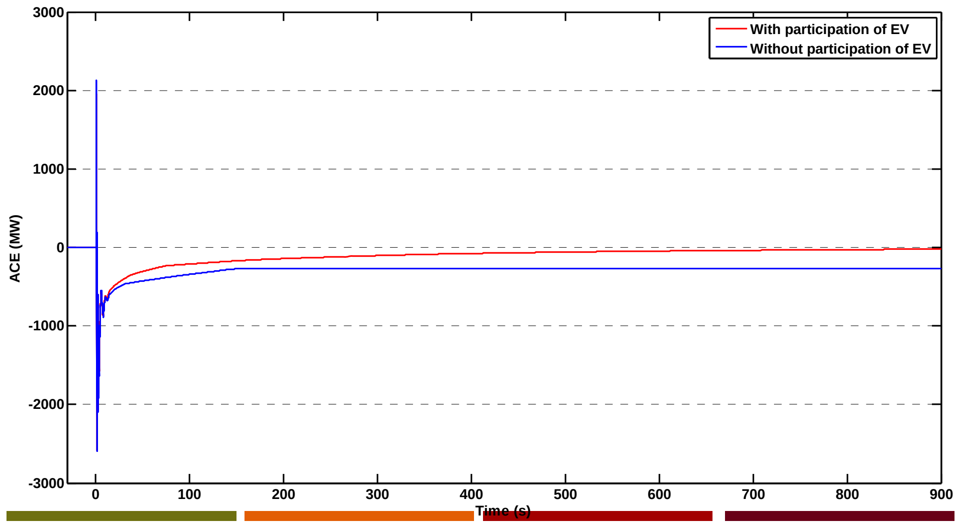
AGC Operation with EV

→ Reduction of the need of reserve levels









Bidding in the Day-ahead Spot and Downward Reserve Markets

minimize cost of purchasing (at wholesale price) electrical energy for charging EV

downward reserve as cheap charging

Income for having available reserve capacity

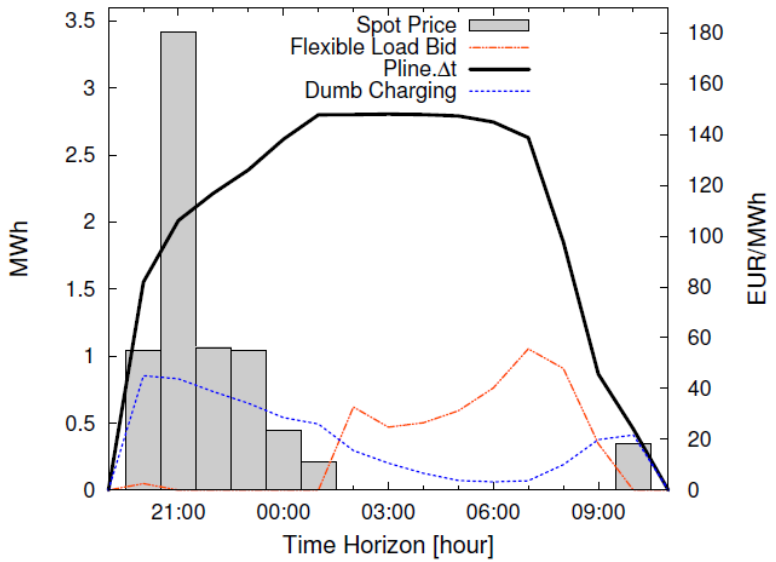
$$\min \sum_{t \in H_i^F} \left(\hat{p}_t \cdot E_{t,k}^F + \hat{p}_t^{down} \cdot P_{t,k}^{down} \cdot \hat{\gamma}_t^{down} \cdot \hat{pf}_t^{down} \cdot \Delta t - \hat{p}_t^{cap} \cdot P_{t,k}^{down} \cdot \hat{\gamma}_t^{down} \right)$$

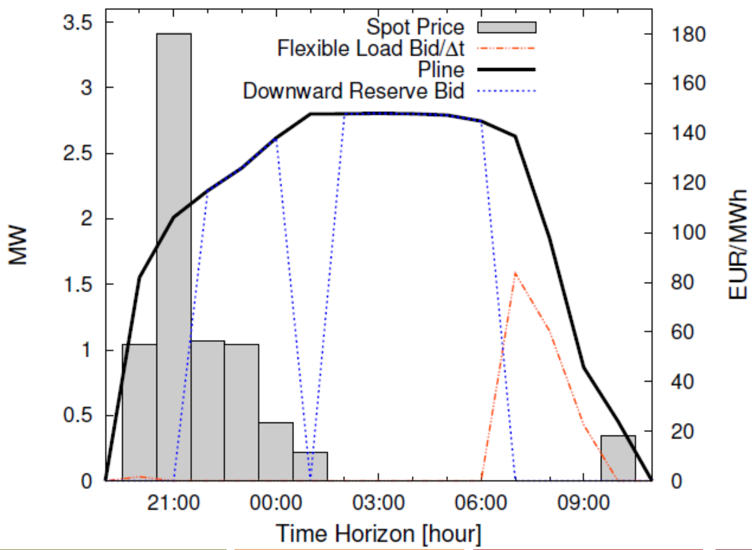
$\hat{\gamma}_t^{down}$: Forecasted system deviation sign

$\hat{pf}_t^{down}$: Forecasted participation factor in secondary reserve

respect the maximum connection power (3 charging levels)

respect the EV owners charging preferences





CONCLUSIONS

- **Electric Vehicles will play an important role in the development of the Smart Grid concepts since they are:**
  - High flexible load device
  - Mobile storage device

- The presence of Electric Vehicles, if properly managed, can:
  - provide several ancillary services;
  - allow a larger integration of renewable power sources;
  - increase system robustness of operation.

- If Smart Charging and other Distributed Intelligent solutions are adopted, the need to reinforce the existing electrical grid and generation infrastructures can be postponed.

http://www.ev-merge.eu/