ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA – ICAI
Instituto de Investigación Tecnológica

Economic Impact of Plug-In Hybrid Electric Vehicles on Power Systems Operation

Camila Fernandes
Pablo Frías
Luis Olmos
Andrés Ramos
Tomás Gómez

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I - Context

- Climate change + search for energy autonomy → target of 20% of renewable energy consumption
- In Spain renewable energy souces (RES) are being strongly promoted by public policies
  - Currently, Spain has 18 GW of wind installed capacity and it is expected that this capacity increases to 40 GW in 2020
- Intermittent generation → highly variable and non controllable output
- EVs are a promising opportunity to mitigate problems caused by intermittency
- However their impact on system functioning will be conditioned by the charging strategy adopted

II - Methodology

- An medium-term operational model is used with the aim of analyzing the impact of the integration of PHEVs with different charging strategies on the Spanish power system operation in 2030

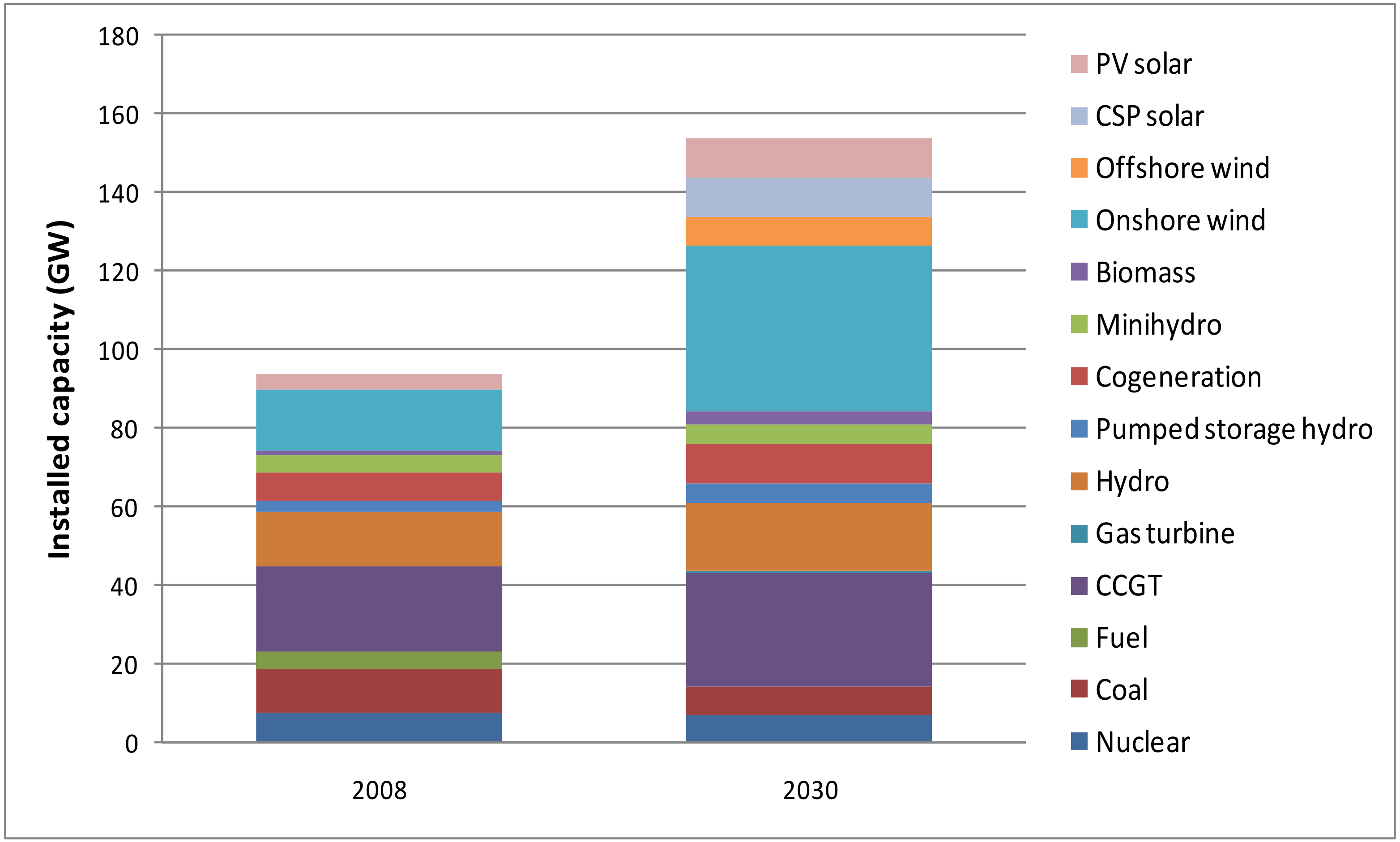
- Charging strategies:
  - Dumb charging: drivers are free to charge their vehicles whenever they want. Charges are equally distributed among hours during which vehicles are plugged-in
  - Smart charging: vehicles are charged when it best suits the system (cost minimization)
  - Vehicle-to-grid (V2G): vehicles are smartly charged and have V2G capability

II.1 - Operational Model

- Daily operational model with a one-year scope
- Unit commitment and economic dispatch are deterministically optimized
- Different events are simulated - unit failures, wind forecasting errors, etc - and corrective actions are applied, such as use of up and down reserve, use of pumped storage units, commitment of gas turbine units in real time. This process is repeated for the 365 of the year
- Detailed operation such as constraints minimum load, ramp rate of thermal units and secondary reserve procurement are included into the daily optimization model
- Other input data are hourly demand, intermittent generation, wind forecasting errors, distributed generation profiles and EVs data
- Main outcomes are generation output by technology, including PS hydro and EVs, spillages, ENS and system costs

II.2 - Assumptions (1)

- Spanish power system in 2030:



II.2 - Assumptions (2)

- Vehicle fleet in 2030: 30 million vehicles → 20% PHEVs (6 million)
- Vehicles' specific consumption = 0.2 kWh/km
- Battery storage capacity = 12kWh
- Three charging strategies: dumb, smart and V2G
- Types of use of PHEVs:

Types of use	Time of use	Average daily driven distance(km)
Commuter	7am - 10am; 5pm - 8pm	35
Business	7am - 8pm	60
Private	7am - 8pm	13
Private	8pm - 12pm	13
Private	12pm - 7am	13

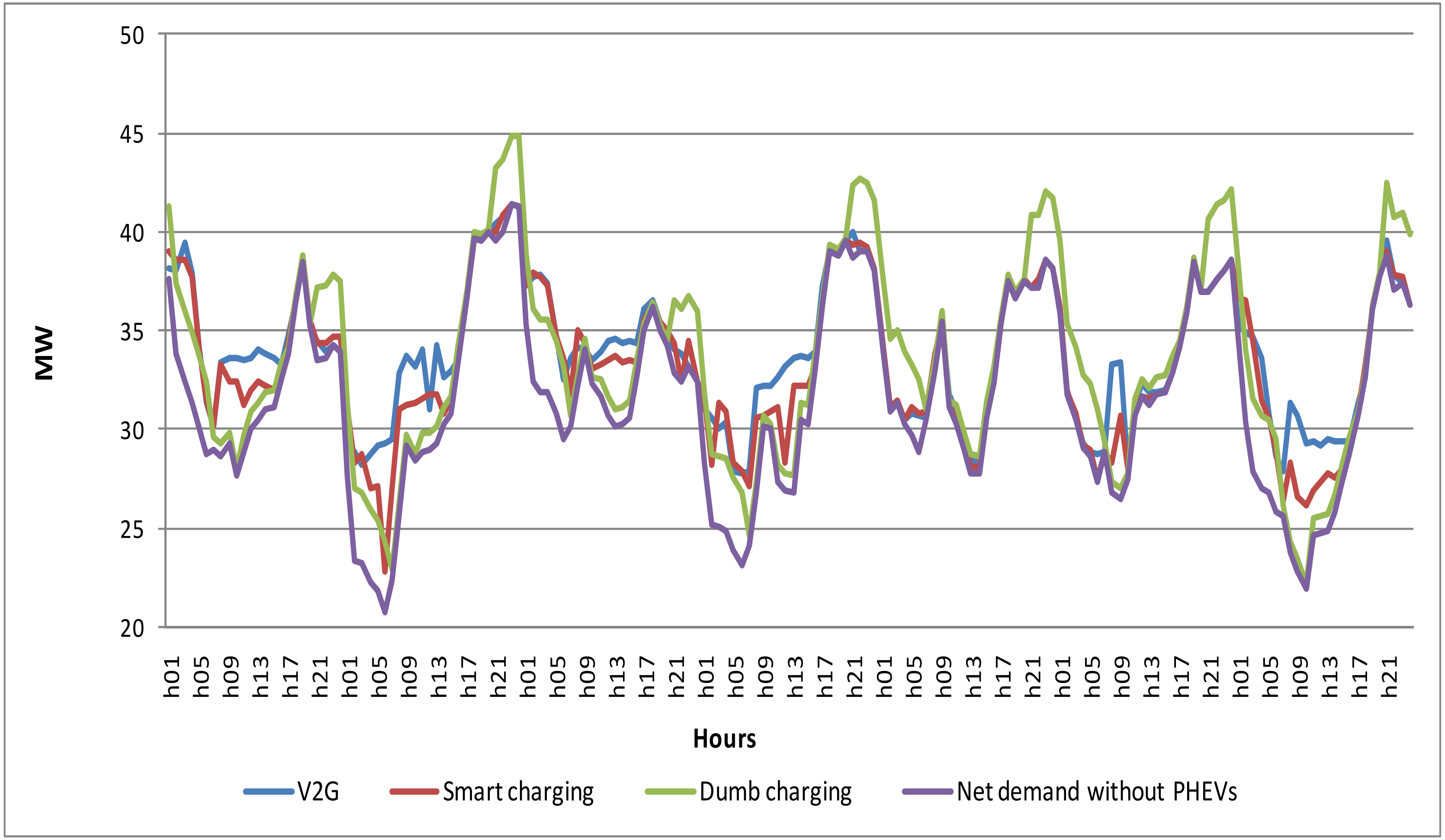
III - Results (1)

- Total electricity demand in 2030

	Reference scenario	Dumb charging	Smart charging	V2G
Demand without PHEVs	344.15	344.15	344.15	344.15
PHEVs consumption	0	16.35	14.51	18.62
PS hydro consumption	9.57	9.80	8.22	6.52
Total demand	**353.72**	**370.30**	**366.88**	**369.29**

III - Results (2)

- Net demand curve in one random week



III - Results (3)

- Energy production, reserves and CO2 emissions

	Reference scenario	Dumb charging	Smart charging	V2G
Thermal generation	135.87	148.67	145.91	145.44
RES generation	213.36	216.67	217.12	217.02
PS hydro generation	4.48	4.95	3.85	2.70
PHEVs generation	0	0	0	4.13
Total (TWh)	**353.72**	**370.30**	**366.88**	**369.29**
Wind curtailment and water spillage (TWh)	9.39	6.34	5.71	5.67
Average up and down reserve (MW)	7,766	7,855	6,698	6,695
CO2 Emissions (Millions of tons)	23.60	29.30	28.47	28.66

III - Results (4)

- System operation costs

	Reference scenario	Dumb charging	Smart charging	V2G
Fuel and CO2 costs	3,512	4,489	4,238	4,180
Wind curtailment and hydro spillage costs	490.45	360.59	329.38	306.60
Up and down reserve costs	455.83	483.60	320.14	308.56
Total (M$)	**4,458**	**5,333**	**4,888**	**4,795**
Average total costs ($/MWh)	**12.60**	**14.40**	**13.32**	**12.98**

IV - Conclusions

- The integration of PHEVs with a dumb charging strategy deteriorates system operation conditions and increases its costs
- On the other hand, when vehicles are smartly charged, improvements on system operation can be achieved and costs can be reduced, especially when V2G is applied
- Therefore, the invesments needed in order to allow smart charging strategies could be more than compensated by the savings resulting from a more efficient power system operation

THANK YOU FOR YOUR ATTENTION!