Power demand estimation and power system impacts resulting of fleet penetration of electric/plug-in vehicles

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Institutions/Research Centers involved: IDMEC/IST; INESC-Porto; IN+/IST; MIT

Companies involved: GALP; EDP; APVE

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1. Questions to be answered:
   • What would be the impact on energy and emissions in the road transportation sector of introducing alternative powertrain technologies in Portugal, mainland and islands?
   • What would be the impact of introducing vehicles requiring electricity on the electrical grid? What changes would be necessary to satisfy the demand?
   • What would be the technology price evolution for Portugal, user point of view and society point of view?

2. Main models

Road transportation sector model: PATTS - Projections for Alternative Transportation Technologies Software to estimate the evolution of fleets along time, allowing the evaluation of the effect of introducing alternative vehicle technologies and alternative energy pathways in a full life-cycle approach.

Inputs: motorization curves over 2010-2050, mobility patterns in vehicle x kilometer over 2010-2050, scrappage rates, sales curve for EV, PHEV, FC vehicles, electricity mix over 2010-2050, biofuel incorporation (%) in fuel over 2010-2050, fuel consumption and emission factors for the different technologies.

Methodology: forecast/backcast with discrete modeling and linear programming.

Outputs: CO₂ in LCA, energy consumption in LCA, local pollutants in WTW, cost for the user, maximum and minimum border lines for multi-scenario analysis of the road transportation sector; regional versus overall impacts.

Application: Portuguese road transportation sector and specific island applications in the Azores.

Grid steady state analysis model: a Monte Carlo approach for simulating different scenarios of EV loads within a distribution network, during a given period. Power flow evaluations using the Newton-Raphson formulation will be performed for every time step, typically 0.5/1 hour, to evaluate grids’ technical indicators.

Inputs: EV penetration, types of EV, mobility patterns (daily commute profiles), EV owner charging behavior, and conventional load diagram.

Outputs: Load diagram (EV+conventional load), voltage profiles, branches congestion levels, and energy losses.

Application: Flores island, S. Miguel island and typical networks from Portugal mainland.

Grid dynamic simulation platform: a primary frequency control model for EV in isolated grids, based on a droop control implementation, using a numerical integration method with a variable time step to perform the necessary simulations.

Inputs: EV penetration, types of EV, mobility patterns (daily commute profiles), EV owner charging behavior, conventional load diagram, generation units representations for dynamic studies,
disturbances on the network or on resource availability. 

Outputs: voltage and frequency fluctuations, machines power and torque variations, EV and conventional generators active and reactive power production. 

Application: Flores and S. Miguel islands.

3. Innovation

- Life cycle integration for energy, CO₂ emissions and local pollutants of different alternative vehicle technologies and energy sources pathways with forecast/backcast tool 
- Monte Carlo application to scenario uncertainty, and estimation of maximum and minimum border lines for multi-scenario analysis of the road transportation sector in the time horizon 2010-2050
- Inclusion of trucks and buses
- Cost and price analysis in the time horizon 2010-2050 for Portugal
- Regarding power system analysis:
  - For steady state:
    - Impact evaluation tool considering the stochastic behavior of EV 
    - Smart charging algorithm from different players’ perspectives
  - For dynamic:
    - Scenarios with generation based only on renewable energy resources
    - Droop control implementation on EV
- Joint evaluation of LCA and power system analysis allowing a full extent study from the transportation and electricity sectors

4. Publications

Books/book chapters

4. Cristina Camus, Tiago Farias, Jorge Esteves, Chapter 8 INTEGRATION OF ELECTRIC VEHICLES IN THE ELECTRIC UTILITY SYSTEMS, In Tech Open access publisher "Electric Vehicles the Benefits and Barriers" Edited by Seref Soylu, 2011

Master thesis


**PhD thesis**


**Per reviewed journal**

1. Published - Cristina Camus, Tiago Farias, The electric vehicles as a mean to reduce CO2 emissions and energy costs in isolated regions. The são miguel (azores) case study, Energy Policy, Volume 43, Pages 153–165, 2012;


Conferences (International)


8. Published- Christos Ioakimidis, Jorge Borges, Dimitris Savvidis. The use of Electric Vehicles in Greece: A Case Study. 3rd European Conference SmartGrids & E-Mobility, Munich, October 17th – 18th, 2011.


11. Published - João P. Ribau, Ana F. Ferreira, Carla M. Silva, Hybrid vehicle alternative fuel converter, energy strategy optimization and application to a fuel cell plug-in hybrid vehicle. IAMF 2011, 8-9 March 2011, Genève, Switzerland;


30. Published - Patrícia Baptista, Cristina Camus, Carla Silva, Tiago Farias, Impact of the introduction of electric based vehicles in São Miguel island, 10th International Conference on Energy for a Clean Environment, Lisbon Portugal, 7-10 July 2009;
31. Published - Patricia Baptista, Carla Silva and Tiago Farias, Impact of the introduction of new vehicle technologies in the Portuguese road transportation sector, 1st Transatlantic NECTAR Conference 2009, Arlington, Virginia USA, 18-20 June, 2009


Conferences (National)
5. Green Feast 2009, Auditório do Estoril, Estoril, 18-25 Setembro 2009
6. MIT-Mid-Program Event, Centro Cultural de Belém, Lisbon, 7 July 2009

5. Role of MIT
Provided know-how. Professor J. Heywood contributed to the most probable visions within the fleet model PATTS and scenario’s combinatorial analysis

6. Role of Industrial partners
Provided industrial visions for fuels future possibilities and power plants data

7. Research impact/Expected benefits
Develop of new charging management strategies, always taking into account the drivers’ requests concerning the foreseen use of the vehicles, assuming the existence of some smartgrid functionalities, like smart-metering and a reliable and efficient communication platform;
Quantify the maximum number of EV that can be safely integrated in a given distribution network;
Minimize the deviations between the energy bought in the markets by the aggregators and the energy sold to EV owners; and the renewable energy wasted in systems with a large integration of intermittent RES;
Flatten, as far as possible, the load diagram of a given network;
Assess the results (energy and CO2 in LCA) of a large number of scenarios through impact indicators applied to road transportation sector (LDV and HDV/Bus);
Develop new procedures to enable EV participation in primary and secondary frequency control schemes;
Assess the effects that a mass introduction and the different daily charging profiles of plug-in vehicles will have in electricity prices.