Role and Impact of Coordinated EV Charging on Flexibility in Low Carbon Power Systems

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1. Introduction

Integration of large shares of Renewable Energy Sources (RES) and Electric Vehicles (EVs) are one of the biggest challenges of future power systems. Even though RESs and EVs can help reduce CO_2 emissions and increase autonomy of power systems they can also bring disadvantages due to their intermittent characteristics. They can reduce the robustness of the power system and they can increase the need for the reserve levels.

2. Model formulation

The goal of a unit commitment problem is to determine the outputs of all the generators with the aim to reduce the overall operational cost.

Modelled technologies:

- Thermal and hydro power plants;
- Renewable energy sources (wind and PV);
- Demand response;
- Pump (hydro) and battery storage;
- Electric vehicles;

System Constraints:

- Generation - load equilibrium;
- Reserve and frequency response equations;
- Generation units technical constraints (ramp rates, minimum up and down times, minimum and maximum output power…);
- Objective function → minimize total system costs;

Electric vehicles model → EVs as one battery storage with variable capacity

- EVs capacity depends on number of vehicles connected to grid;
- EVs model includes different: behaviour patterns (personal vehicles and public transportation), availability, range/trip length (short, medium and long), battery size;
- Three charging modes are modelled:
  - Passive charging;
  - Grid-to-Vehicle G2V;
  - Vehicle-to-Grid V2G;

3. Scenarios

Three different generation mixes are modelled:

1. Dominantly nuclear-coal thermo system (non-flexible thermo – nonFTh);
2. Dominantly coal-gas thermo system (flexible thermo - FTh);
3. Dominantly hydro-thermo system (decently flexible system - HyTh);

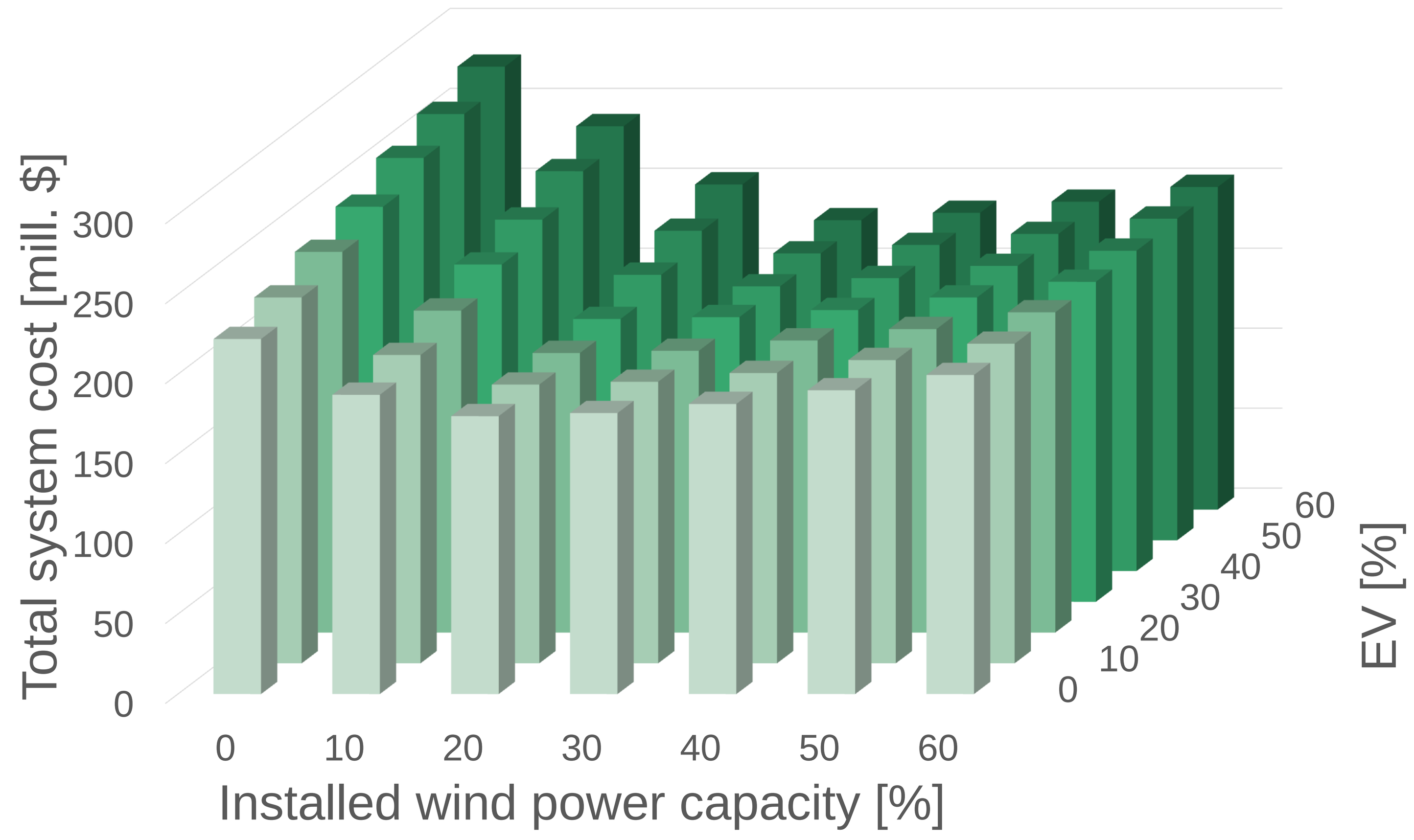
Gen. Type	NPP [%]	Coal [%]	Oil [%]	CGT		HPP		
				Open [%]	Comb. [%]	Acc [%]	Run. [%]	Pump [%]
nonFTh	45	40	5	10	0	0	0	0
FTh	15	20	10	40	15	0	0	0
HyTh	20	20	0	10	0	15	20	15

- Total system cost depends on the energy mix: FTh >nFTh> HyTh;
- Hydro – Thermo system has the lowest cost compared to other systems (lower operational cost);
- Different scenarios behave differently when they are subjected to changes (e.g. increase in RESs or EVs);
- Since hydro units are fully run in the base case, additional demand (in case EV) is covered with expensive gas turbines;

4. Results

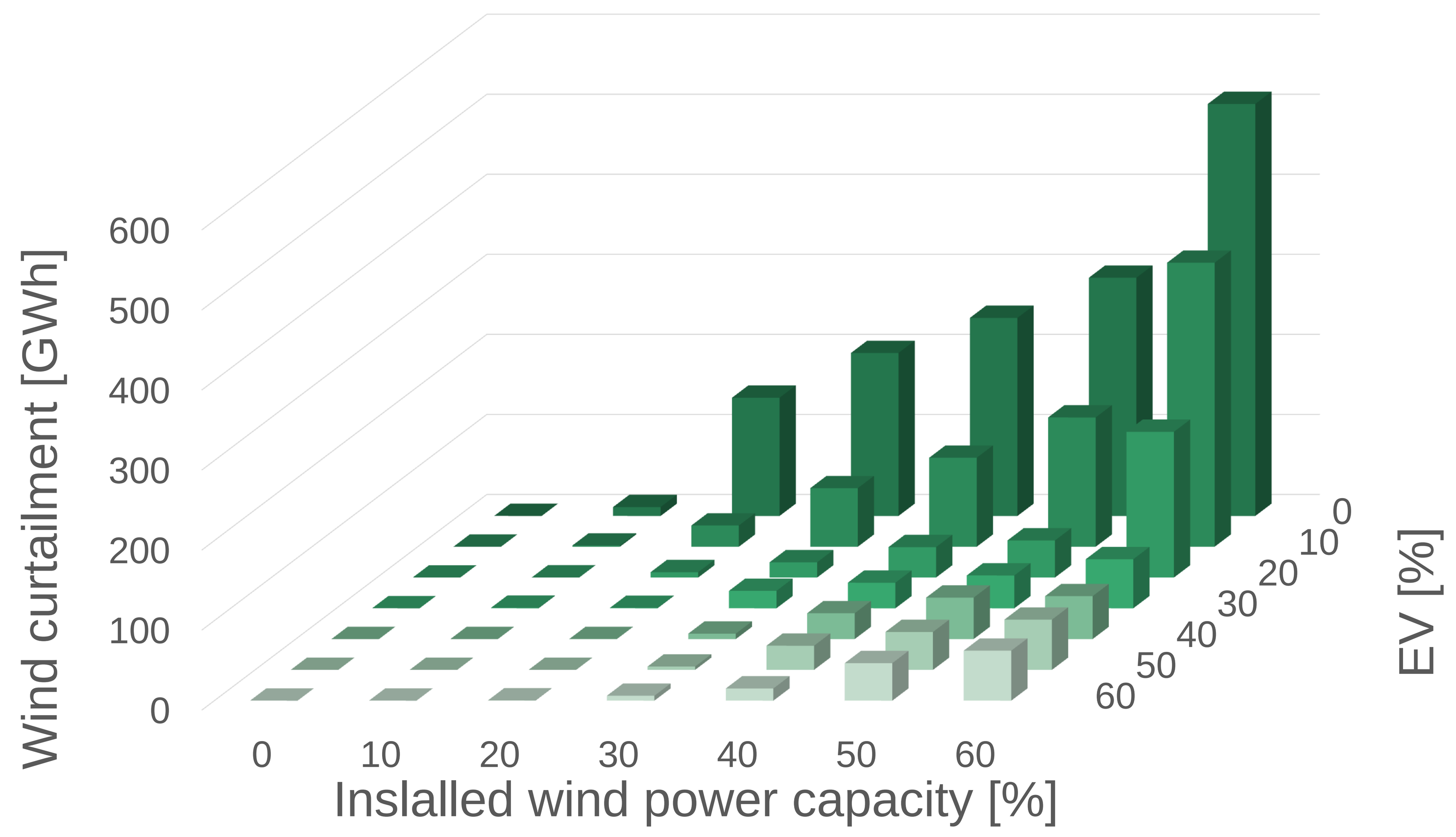
Total system cost (observed only for nonFTh case)

- Increase in EVs share → cost increase;
- Increase in Wind capacity until breakpoint → cost decrease (for 0 EVs breakpoint is at 20 %; for 60% EVs breakpoint is at 30%);
- Increase in Wind capacity after breakpoint → cost increase;
- Larger share of EVs enables more intermittent RES;



Wind curtailment (observed only for nonFTh case)

- Wind curtailment increases with higher share of wind power plants;
- Increase in EVs share → significant drop in wind curtailment;
- EVs as flexible technology enables less curtailed wind energy;



5. Conclusions

- EVs have significant impact on power system scheduling;
- Depending on their charging mode EVs can increase or decrease peak load;
- EVs with smart charging can smooth the daily load curve;
- EVs in nF systems, in G2V concept, can be used as tool for improving system flexibility;
- EVs with smart charging are useful for mitigating the negative effect of RES-E;

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