Network tariff design with electric vehicles and distributed energy resources

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Overview

Introduction and motivations

Electric vehicles as a key-element of energy transition

- Small but dynamic local trends of EV diffusion
- Disruptive technology for power grids :
  - For EV owners : huge increase of electricity bills
  - For power grids : between stabilization and destabilization ?
  - For renewable energy : source of flexibility ?

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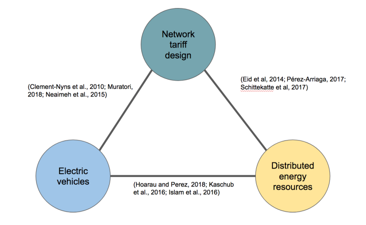
    - For renewable energy : source of flexibility ?
- But in parallel, an other disruption happening in power grids, with distributed energy resources (DERs) with
    - solar PV
    - home lithium-ion batteries
- Synergies between DERs and EVs ?
- How do the economic rules shape the integration of EVs in power grids and their interaction with DERs ?

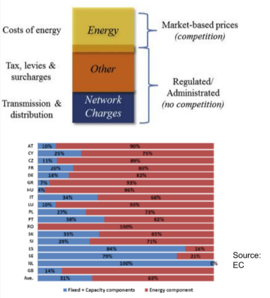
Related literature



- EV integration in power grid : massive uncontrolled charging should increase grid costs
- EV/DERs interaction : synergies (lower costs and GHG) conditioned by techno-economic factors
- Tariff design : next slide

Tariff design with DERs

What is network tariff design ?



Principles of tariff designs :

- cost reflexivity
- grid cost recovery
- fairness between users

Tariff design with DERs

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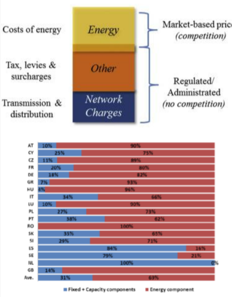
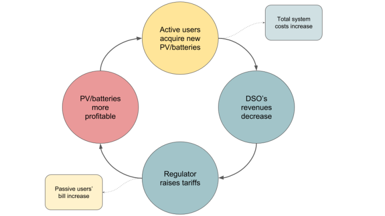


Source: EC

Tariff design with DERs : towards a vicious circle ?



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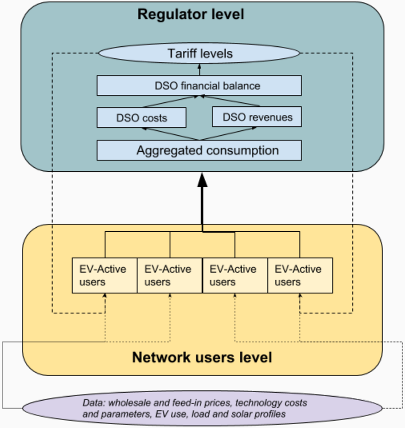
Research questions of this paper

- How can EV be included in network tariff design ?
- What are the resulting effects of DERs and EV adoption on network tariff design ?
- What are that resulting effects of tariff design on both DERs and EVs ?

Methods

Model framework



- Stackelberg game between the regulator and network users
- Regulator chooses a tariff structure and ensure network cost recovery. Grid costs are all sunk
- active users minimize their electricity bill by investing in DERs and/or smart charging their EV
- EV adoption is exogenous
- "commuting" EVs (away during the day)
- Model solved iteratively

Scenarios and evaluation

Tariff structure :

- Volumetric with/o net-metering (EUR/kWh)
- Capacity (EUR/kW)
- Fixed (EUR) (*used as a reference case*)

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Diffusion scenarios :

- Low EV - Low Active (10%-10%)
- Low EV - High Active (10%-50%)
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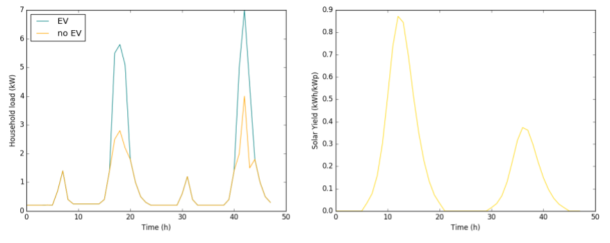
Evaluation proxies :

- Efficiency : variation of total system cost
- Equity : variation of passive users' welfare
- EV incremental cost : costs difference between EV and non-EV owner
- DER adoption : average DER capacity from active users

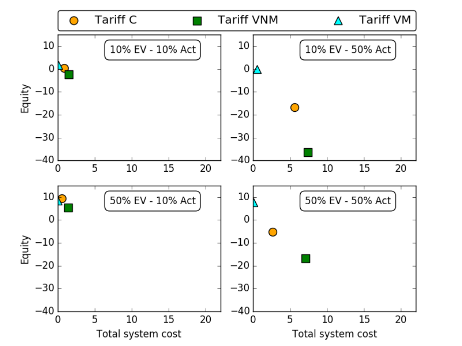
Data



Parameter	value	Parameter	value
PV panel/battery lifetimes	20/10 years	(dis)charging efficiency	90%
PV investment cost	$1300 EUR/kWp$	Battery investment cost	$200 EUR/kWh$
Discount rate	5%	Maximum solar PV	5kW
Daily travel distance	40km	plug power	3kW
EV battery capacity	40kWh	Charging hours	5pm-7am
"Normal" annual power consumption	6500kWh	Annual solar yield	1160kWh/kWp
"Normal" electricity price	$0.18 EUR/kWh$	Energy/Network ratios	45-35%

Results

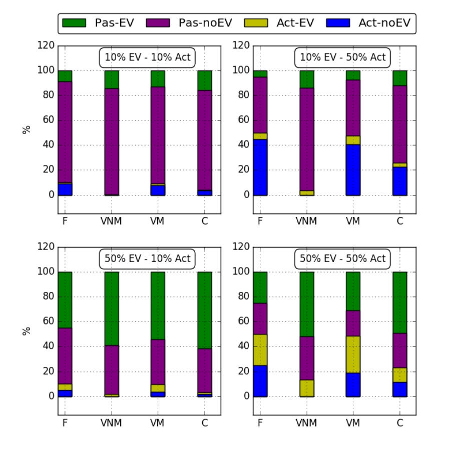
Opposite effects of EVs and active users



- Fixed tariff do not incentivize for DERs and do not change EV costs
- Volumetric without metering reduce over-incentives
- Vol net-met tariff strongly incentivize for solar PV, but EV greatly reduce the effect on tariff
- Capacity tariff incentivize for batteries and create similar issues that vol net-met

Distribution of network costs between users

Who is bearing network costs ?

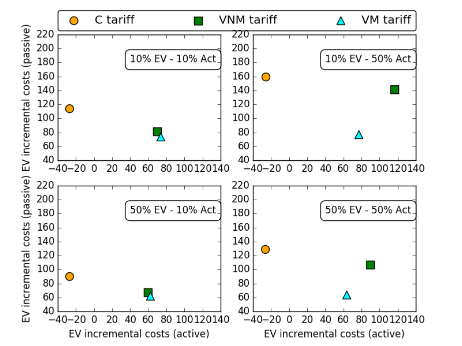


With vol. net-met and cap tariffs :

- active noEV user do not contribute to network costs
- EV owners particularly contribute to network costs

Effects of DERs on EV incremental cost

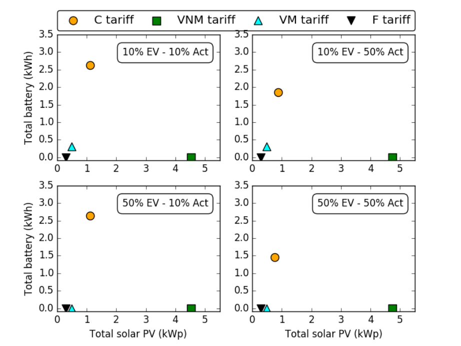
How are EV incremental costs impacted with tariff changes ?



- Under capacity tariff, huge discrepancy between active and passive EV incremental costs
- Vol. net-met tariff, EV incremental cost increases are higher than network charges increase

Spillovers on DER adoption

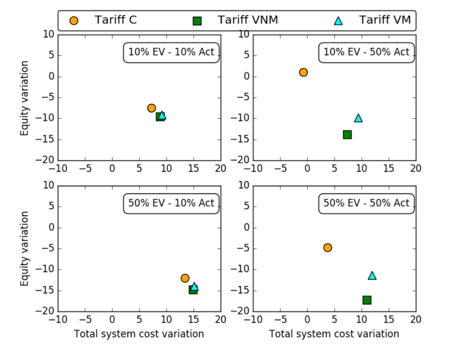
If EV tend to lower tariffs, how would it affect DERs profitability ?



- No spillover from EVs with vol. net-met
- With capacity and vol without net-met, battery adoption severely impacted, solar PV not impacted

Effect of variable network costs structure

We assume now a variable component in grid costs



- EV charging increases grid costs and therefore network charges for all users
- Active EV owners contribute to decrease total system cost
- Capacity tariff cost-reflective and improve equity and efficiency
- Other tariff do not improve equity

Conclusion

Conclusion and future works

With volumetric and capacity tariffs :

- EV and DERs have counterbalancing effects on tariff design
- Through the grid cost recovery, EV and DERs induce externalities on each other
- EV owners bear a very significant shares of network costs

Future works :

- Generalize to electrification and self-supply case study
- Extend the analysis to higher-voltage networks (including workplaces, charging stations)
- Analytical model to explain better incremental effects

Conclusion

Thank you for you attention !
Any questions ?

Appendix

Best responses of active users