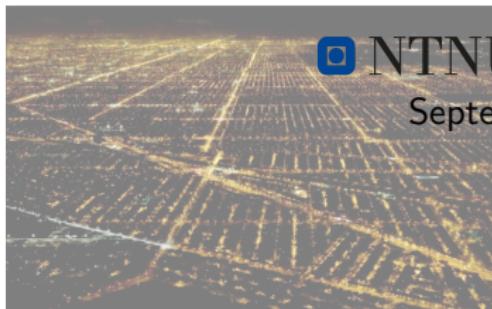


Can we charge everyone's electric vehicles without reinforcing the electric grid?



Salman Zaferanlouei

NTNU Battery Seminar
Hotel Scandic Lerkendal
Trondheim



NTNU | September 23, 2021



Norwegian University of
Science and Technology

The answer is yes

Table 1: Charge Scheduling Strategies

Method	Max EV hosting Capacity	
Uncoordinated/Dumb Charging	20%	
Market price based	36%	
Market price and Congestion management based	100%	

The presentation goal

- ▶ **Purpose:** To show how to coordinate **Batteries in the Grid: (EVs):** Large-Scale EV charge scheduling platform to avoid congestion
- ▶ **Phase I:** Background and Motivation
- ▶ **Phase II:** EV Statistics
- ▶ **Phase III:** Case Study

Project Name:	BATTPOWER
Presentation Time:	10 min

Phase I: Background and Motivation

Electricity Grid

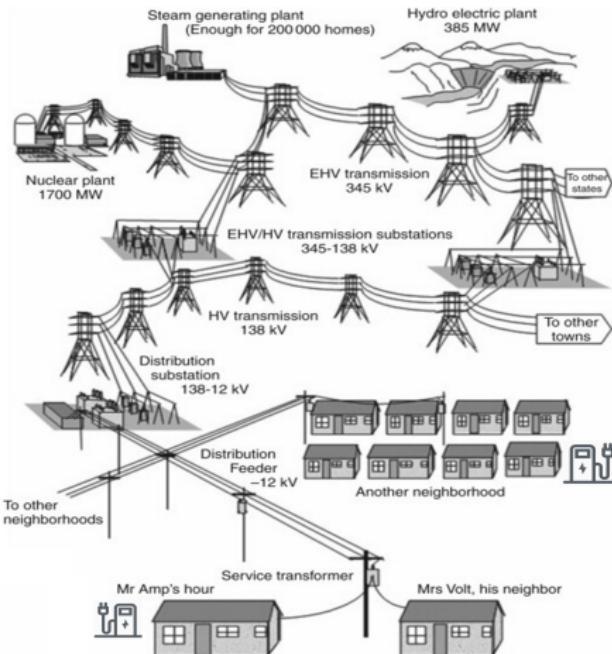


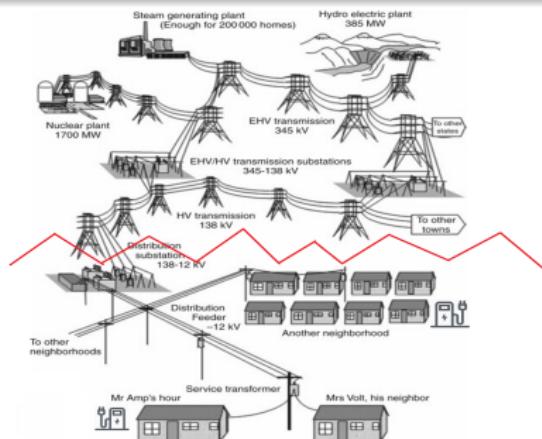
Figure 1: [www.sciencedirect.com/science/article/pii/B9781845697846500019]

Sustainability/Green shift/CO₂ reduction

For many reasons power electricity grid is facing decentralization

- ▶ Phasing out coal (carbon-heavy sources of production) and nuclear power plants

This chain between large power producers and consumers is weakened.

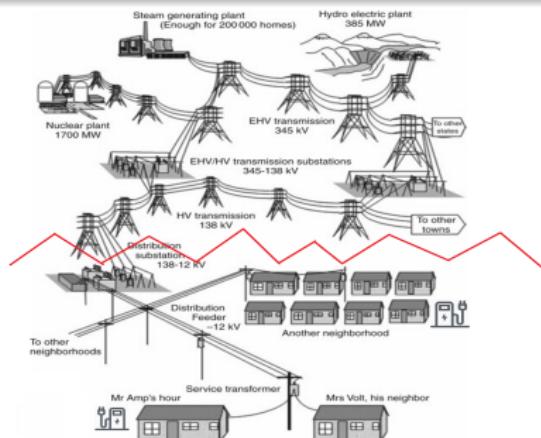


Sustainability/Green shift/CO₂ reduction

For many reasons power electricity grid is facing decentralization

- ▶ Phasing out coal (carbon-heavy sources of production) and nuclear power plants
 - ▶ Increase penetration of solar and wind production

This chain between large power producers and consumers is weakened.



Background: cont.

Items

- ▶ Green shift in electricity systems is needed for the reduction of CO₂ emissions



Figure 2: A Typical Power System [Rochester Gas & Electricity]

Background: cont.

Items

- ▶ Green shift in electricity systems is needed for the reduction of CO₂ emissions
 - ▶ Integration of Distributed Energy Resources (DER) is a huge challenge

Note

DER includes Renewable Energy, Energy Storage, Electric Vehicles and Flexible Demand

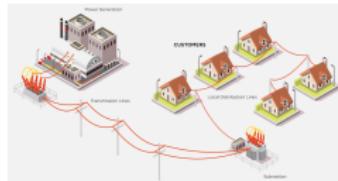


Figure 2: A Typical Power System [Rochester Gas & Electric]

Background: cont.

Items

- ▶ Green shift in electricity systems is needed for the reduction of CO₂ emissions
 - ▶ Integration of Distributed Energy Resources (DER) is a huge challenge
 - ▶ Grid companies must be able to analyse the impacts of DER

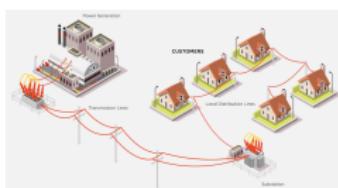


Figure 2: A Typical Power System [Rochester Gas & Electricity]

Background: cont.

Items

- ▶ Green shift in electricity systems is needed for the reduction of CO₂ emissions
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- ▶ Grid companies must be able to analyse the impacts of DER

Note

Optimal Power Flow (OPF) solvers are essential



Figure 2: A Typical Power System

[Rochester Gas & Electric]

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Background: cont.

Items

- ▶ Green shift in electricity systems is needed for the reduction of CO₂ emissions
 - ▶ Integration of Distributed Energy Resources (DER) is a huge challenge
 - ▶ Grid companies must be able to analyse the impacts of DER
 - ▶ The integration of DER in smart grids calls for **much more sophisticated solvers** for OPF



Figure 2: A Typical Power System [Rochester Gas & Electricity]

Challenges in the planning and operation of the grid

- ▶ **Planning:** Optimizing the right type, size and timing of new grid investments
 - ▶ Local generation (e.g. PV) and increased load (e.g. EVs) can be located in areas where the grid is weak
 - ▶ Energy storage and demand flexibility are alternatives to grid reinforcements

Challenges in the planning and operation of the grid

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 - ▶ Energy storage and demand flexibility are alternatives to grid reinforcements
- ▶ **Operation:** Optimize the use of controllable assets such as energy storage and flexible demand to secure, reliable and economic operation of the distribution grids. This means:
 - ▶ Making the right use of Demand Response
 - ▶ being able to value the use of end-user flexibility for local or system-wide grid services
 - ▶ Simulating and optimizing the grids in the presence of **future local markets for energy and flexibility**

Limitations of traditional grid operation and planning

Notes

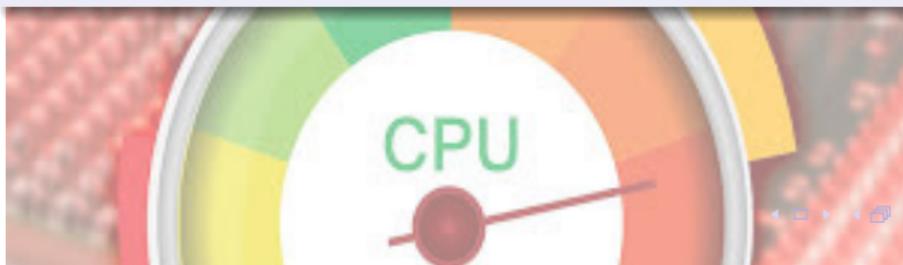
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Limitations of traditional grid operation and planning

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- ▶ Classical single-period OPF does not offer a possibility for optimal operational scheduling of storage and flexible demand
- ▶ We therefore aim to develop the foundations for a new generation of Multi-Period OPF (MPOPF) solvers
 - i. Solves the OPF problem over several coupled time-steps
 - ii. Computation time is an issue when using both commercial or free optimization solvers



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- ▶ MPOPF is an extremely challenging scientific task:
 - i. Nonlinearity
 - ii. Large-scale problem with respect with to time and space
 - iii. Involves stochastic generations and load

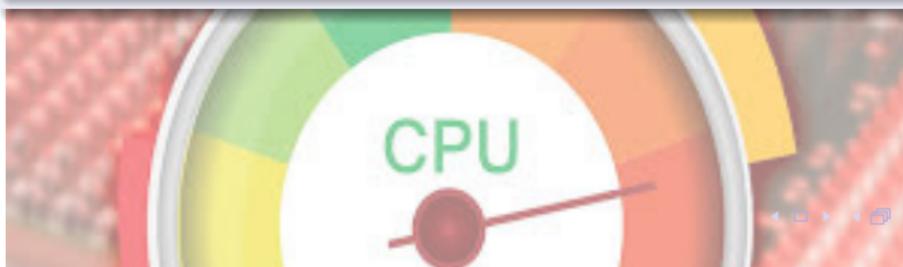


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Hardware is reaching its limit with respect to CPU clock speed



Solution:

High-Performance Solver [1-2]

- ▶ Algorithmic design tailored to the conventional OPF algorithms speed-up the solution proposal
- ▶ Prototype model shows convincing results for real-sized system with distributed renewables, storages and EVs
 - i. A high-performance and memory-efficient sparse algorithm
 - ii. Utilizing the structure of the underlying mathematical formulation

1. S. Zaferanlouei, H. Farahmand, V. V. Vadlamudi, M. Korpås, "BATTPOWER Toolbox: Memory-Efficient and High-Performance Multi-Period AC Optimal Power Flow Solver", IEEE Transactions on Power Systems, Jan. 16th, 2021.

2. S. Zaferanlouei, et al., "BATTPOWER Application: Large-Scale Integration of EVs in an Active Distribution Grid —A Norwegian Case Study", Under review in the journal of EPSR

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Benefits

- ▶ Optimal utilization of **stored energy** and **flexibility** where and when it creates the highest value for the system

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- ▶ Optimal utilization of **stored energy** and **flexibility** where and when it creates the highest value for the system
- ▶ Can be used for grid planning, grid operation and local markets

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Power System— Today

[Reference: Joint Research Centre: European Commission Web page

<https://ses.jrc.ec.europa.eu/smart-grid-interactive-tool-non-flash>



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of
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Power System— Future

[Reference: Joint Research Centre: European Commission Web page

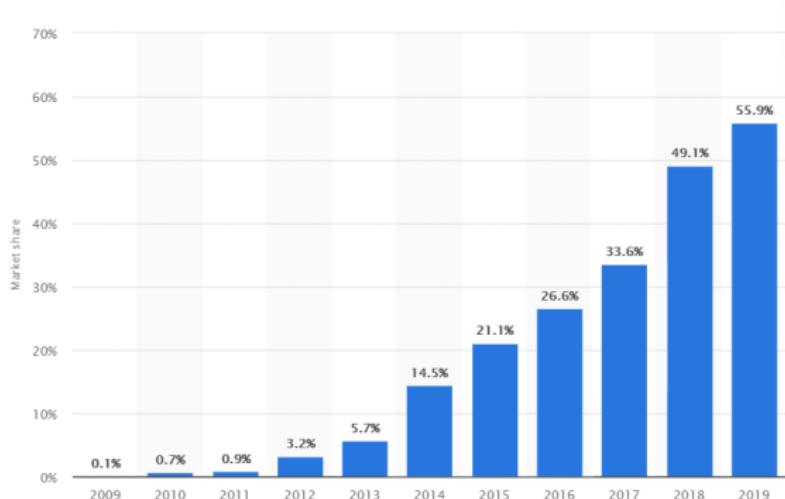
<https://ses.jrc.ec.europa.eu/smart-grid-interactive-tool-non-flash>  NTNU | Norwegian University of Science and Technology

Phase II: **EV Statistics**

Statistics

Market Share

Market share of electric cars (BEV and PHEV) in Norway from 2009 to 2019[ssb.no]



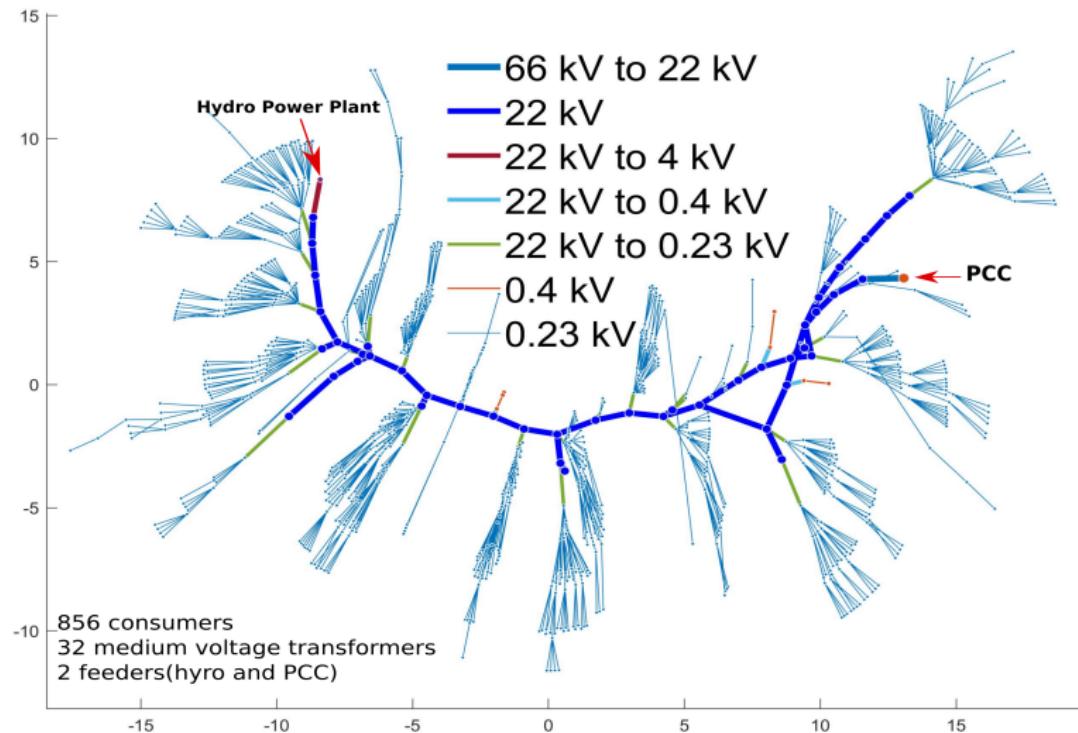
Penetration

Around 10% EV penetration in Norwegian transport sector. The Norwegian Parliament has decided on a national goal that all new cars sold by 2025 should be zero-emission (electric or hydrogen)^a.

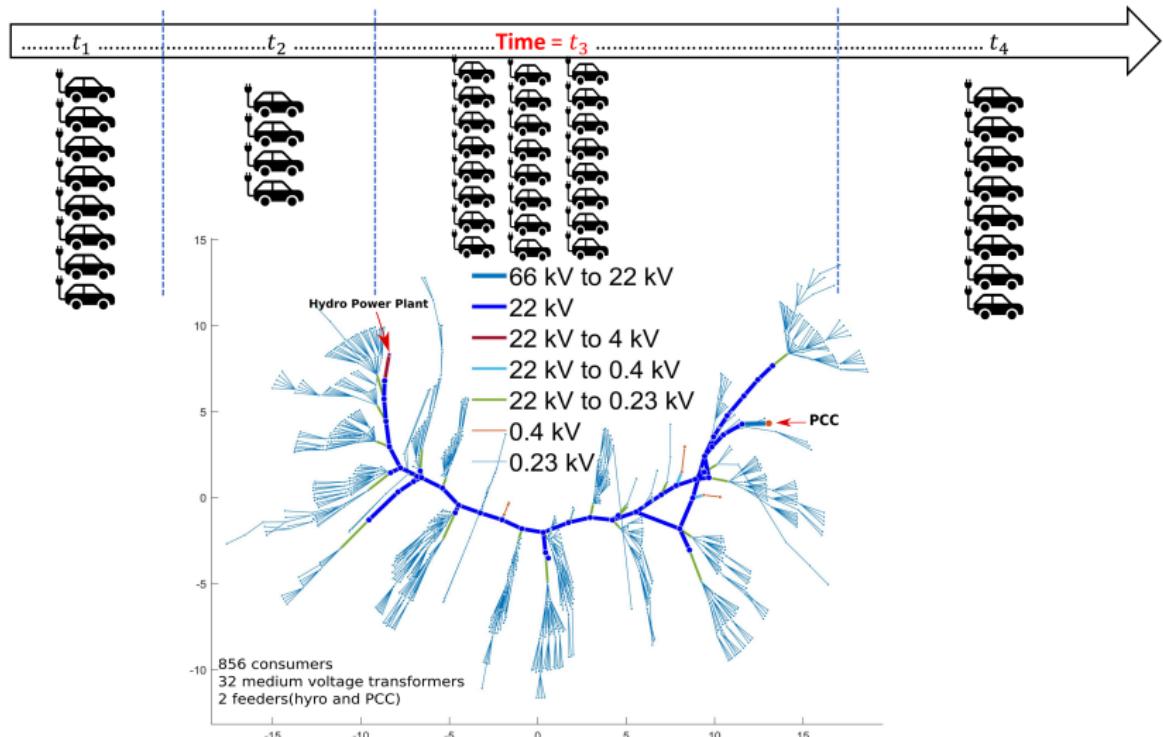
^a<https://elbil.no/>

Phase III: Case Study

Steinkjer Demo: a Real Distribution Grid



Simulations through time



Simulation Results

Table 2: Charge Scheduling Strategies

Method	Description	Max EV hosting Capacity
Uncoordinated/Dumb Charging	Charge on arrival time	20%

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Market price based	<p>Oslo area, Market price profile Sep. 23 2021</p>  	36%

Simulation Results

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Thank you for your attention!

