Welcome to the webinar: The Future Power System with Integrated Energy Storage

We will start shortly

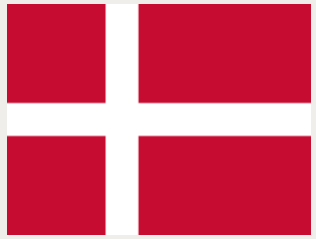

Image source: Siemens
(https://new.siemens.com/global/en/products/buildings/fire-safety/applications/li-ion-battery-storage-system.html)

CIGRE Next Generation Network Denmark (CIGRE NGN DK)

Gustavo Gontijo

gfgo@et.aau.dk

cigre Next Generation Network

cigre Denmark

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Gustavo Gontijo

- Joined CIGRE NGN DK steering committee in 2021
- BSc in Electrical Engineering with emphasis in power system analysis from the Federal University of Rio de Janeiro (UFRJ), Brazil
- Intern in the R&D center of the brazilian energy company Petrobras – research about wind turbines and photovoltaic systems
- MSc in Power Electronics from the Federal University of Rio de Janeiro, Brazil – research about converter topologies and control techniques to improve power quality of wind turbines
- Researcher with the Laboratory of Power Electronics and Medium Voltage Applications (part of UFRJ) – research about microgrids
- Currently with Aalborg University (Denmark) as PhD student with Professor Remus Teodorescu as a supervisor
- Research about modular multilevel converters with integrated energy storage for medium-voltage applications

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What is CIGRE NGN DK?

CIGRE Next Generation Network (NGN) Denmark is the affiliation of CIGRE Denmark for **young members** (students/less than 10 years in the industry).
CIGRE Denmark is the Danish chapter of a large knowledge sharing organization for large electric power systems, that publishes articles, hosts Working Groups (WGs), conferences and symposia.
The steering committee of CIGRE NGN wants to **create and host events where young engineers can learn and network**. We are arranging a series of technical webinars and (when possible) physical events.

Website: https://cigre.dk/new-generation-network.html

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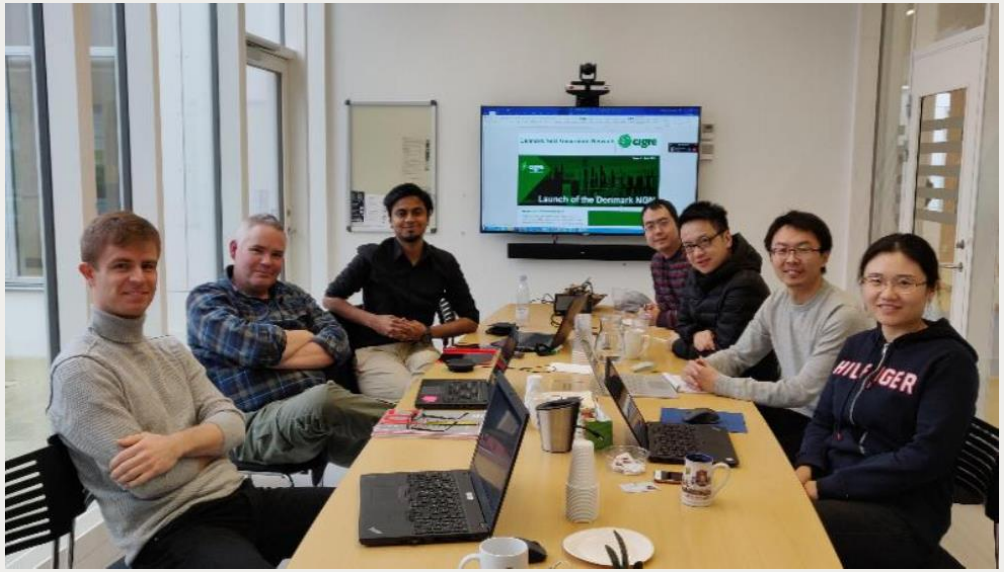
CIGRE NGN DK Facts

- Kick-off in March 2018
- Currently over 80 members
- Inspirations from CIGRE Paris Session 2018
- Experience of peers from the UK, the Netherlands and Germany
- Interest of Danish National Committee (NC)



Cigre Denmark National Committee

- Claus Leth Bak, Chair - **Aalborg University**
- Jørgen S. Christensen - **Dansk Energi**
- Troels Stybe Sørensen - **Ørsted**
- Joachim Holbøll - **Danish Technical University** (**DTU**)
- Philip Carne Kjær - **Vestas**
- Peter Weinreich-Jensen - **Siemens**

→ Secretary: Anette Lundsgaard Larsen - **AAU**

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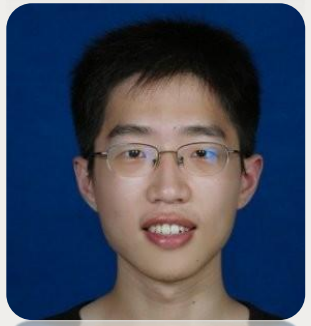
Steering Committee: The Team

Daniela Pagnani

Eli Maria Stenseth

Lennart Petersen

Syed Hamza Kazmi



Heng Wu

Gustavo Figueiredo Gontijo

BREAKING NEW GROUND
AALBORG UNIVERSITY

Vestas

ENERGINET

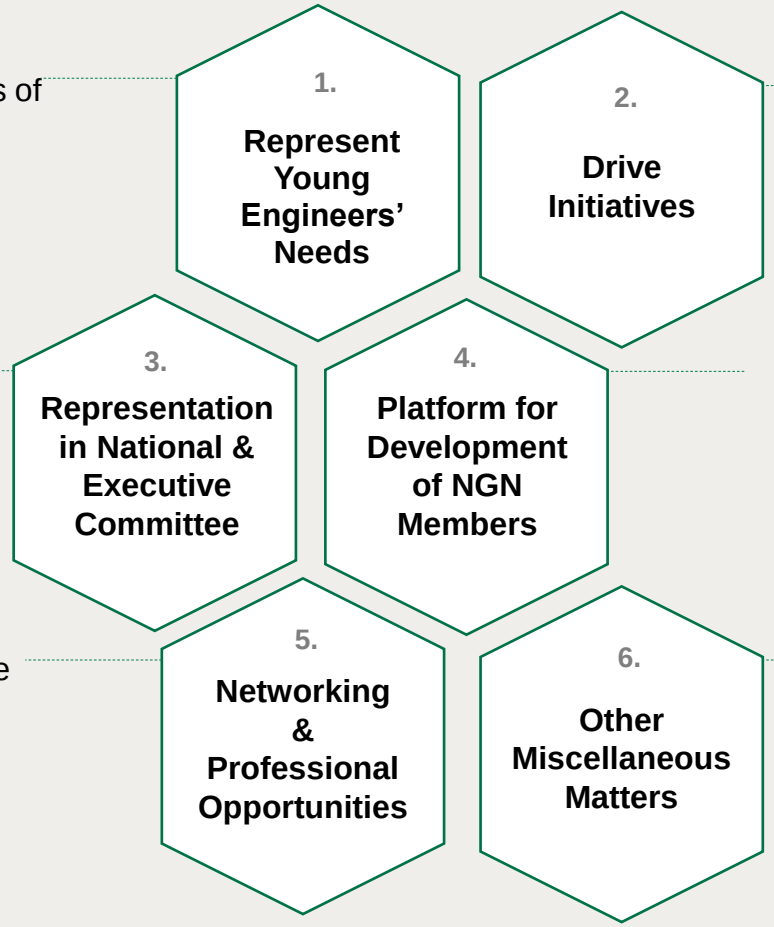
Ørsted

DTU
Technical University
of Denmark

cigré DK NGN

Scope of CIGRE NGN DK

- How can CIGRE activities reflect the needs of young engineers?



- Member initiatives within CIGRE-DK (e.g., tutorials, technical visits)

- Represent NGN within Danish NC
- Participation in CIGRE Central Office initiatives

- Provide structure for personal development / advice through mentoring.
- Provide structure to connect with contact persons in each CIGRE-DK member company / university

- Provide links into each study committee
- Provide the process for selecting NGN members to attend Paris session & symposia
- Organize the coordination between members at the event

- Provide opportunities for other initiatives
- Possible collaborations with other Student and Young Engineers bodies like IEEE, IET etc.

Membership Benefits

Knowledge Sharing and Dissemination	Professional Networking	Personal Development
Get access to NGN activities in Denmark such as workshops, guest lectures, technical visits, etc.	Get in touch and collaborate with experienced professionals from the field via CIGRE international network	Build your professional skills by organizing, presenting and sharing technical knowledge

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NGN Events

Events organised in 2020:

- Webinar ”Offshore Wind Energy”, in collaboration with NGN UK. Led by our SC members in Ørsted and AAU
- Webinar ”Offshore Energy Hubs”, in collaboration to NGN NL. Led by our SC members in Energinet and Ørsted

Events in the pipeline (technical visits):

- Visit to Ørsted’s Avedøre combined heat and power (CHP) station and wind farm
- Visit to Energinet’s Vester Hassing substation and HVDC Konti-Skan connection to Sweden
- Visit to Energinet’s headquarters, Endrup substation and COBRAcable HVDC connection to the Netherlands
- Visit to Vestas’s wind turbine nacelle production facility

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Avedøre Power Station and Wind Farm Visit

- Event at Ørsted's Avedøre power station (close to Copenhagen)
- Visit Avedøre offshore wind farm and combined heat and power station
- Technical tour to the power station

Source: https://ramboll.com/projects/re/avedore_power_station .

Vester Hassing HVDC Substation Visit

- Event at the Vester Hassing substation in North Jutland
- Event in collaboration with Energinet and AAU
- Konti–Skan HVDC connection with Sweden

Source: https://en.wikipedia.org/wiki/Konti%E2%80%93Skan#/media/File:KontiSkan_Vester_Hassing_converter_station_2011.jpg

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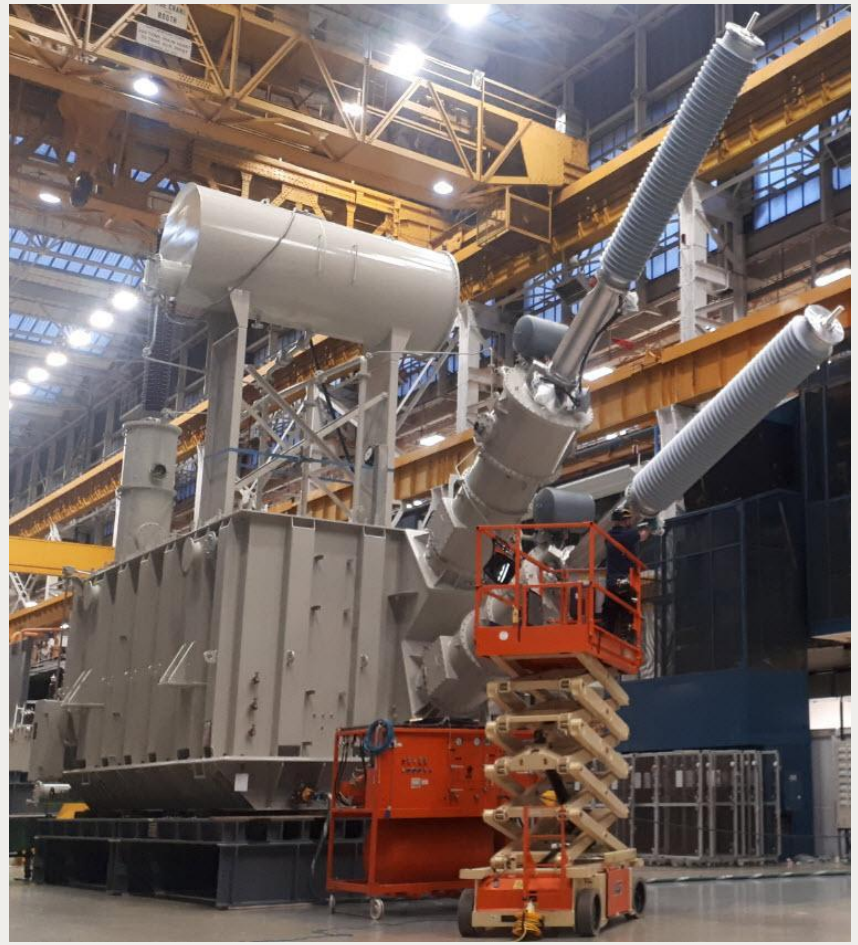
COBRAcable HVDC Visit

- Event led by Energinet
- Visit to Energinet headquarters in Fredericia and Endrup substation
- HVDC connection to the Netherlands

Source: http://www.cobracable.eu/ .

Vestas Nacelle Production

- Event led by Vestas
- Technical talks/tutorials
- Technical tour to the factory to see how the power equipment are manufactured



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Joining CIGRE NGN DK

- Become a CIGRE member (**free** for students or through affiliation with companies and universities with Collective membership)
- Registration form for CIGRE NGN DK (**free** as well) at:
  https://cigre.dk/new-generation-network.html

Young Cigré Denmark
@youngcigredk

Young Cigre Denmark
@youngcigredk

Welcome to the webinar:

The Future Power System with Integrated Energy Storage

Organised by CIGRE NGN Denmark

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Welcome to our speakers:

Lisa Calearo

DTU Technical University of Denmark

Lisa Calearo is a CIGRE NGN DK member and is currently pursuing the Ph.D. degree on "Large-Scale Integration of Distributed Energy Resources in Islanded Power Systems considering User Needs" with DTU. She received the double M.Sc. degree in electrical engineering from the University of Padova (Italy) and in sustainable energy from DTU. Her current research interests include electric vehicles power system integration and grid service support, battery degradation, distribution grid modelling, simulation and testing.

Welcome to our speakers:

George Alin Raducu

VATTENFALL

George Alin Raducu holds a M.Sc. degree in Power Electronics and Drives from Aalborg University. Currently, he is working in Vattenfall Vindkraft Denmark as Product Manager. His main focus areas are in regard with optimisation and control solutions tailored for wind farms, solar parks as well as hybrid power plants, i.e. the integration of different renewable energy generation systems together with storage systems and/or hydrogen units under the same grid connection point.

We would like to thank the speakers for accepting this invitation and we wish them a good presentation!

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Battery Electric vehicle integration into the grid: experiences from the Danish V2G project ACES

Lisa Calearo, PhD student

lica@elektro.dtu.dk

Next Generation Network

Denmark

For power system expertise

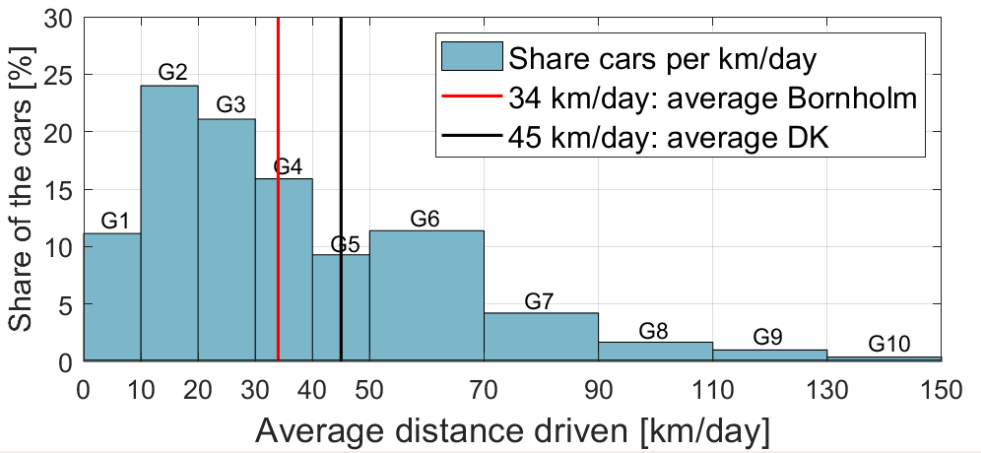
Agenda

- Charging needs and grid impact
- Primary Frequency Control – V2G
- Consequences in term of battery degradation
- Conclusion & other work in progress

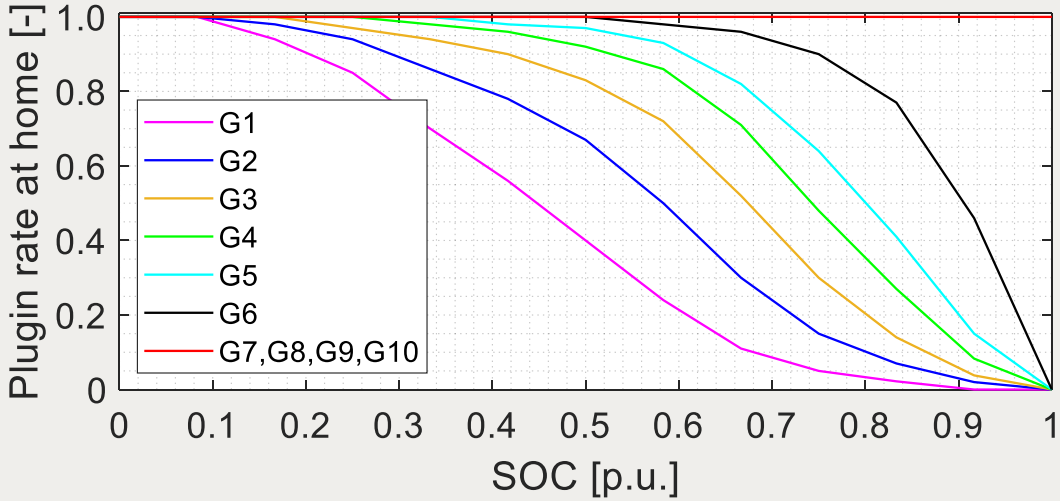
The local grid – the driving behaviour matters

Considering realistic driving/charging behaviour, what's the expected coincidence factor and total charging power of a 100% EV scenario?

- Historical driving characteristics of private conventional vehicles from Denmark



- Home plug-in behavior of EVs from Japan

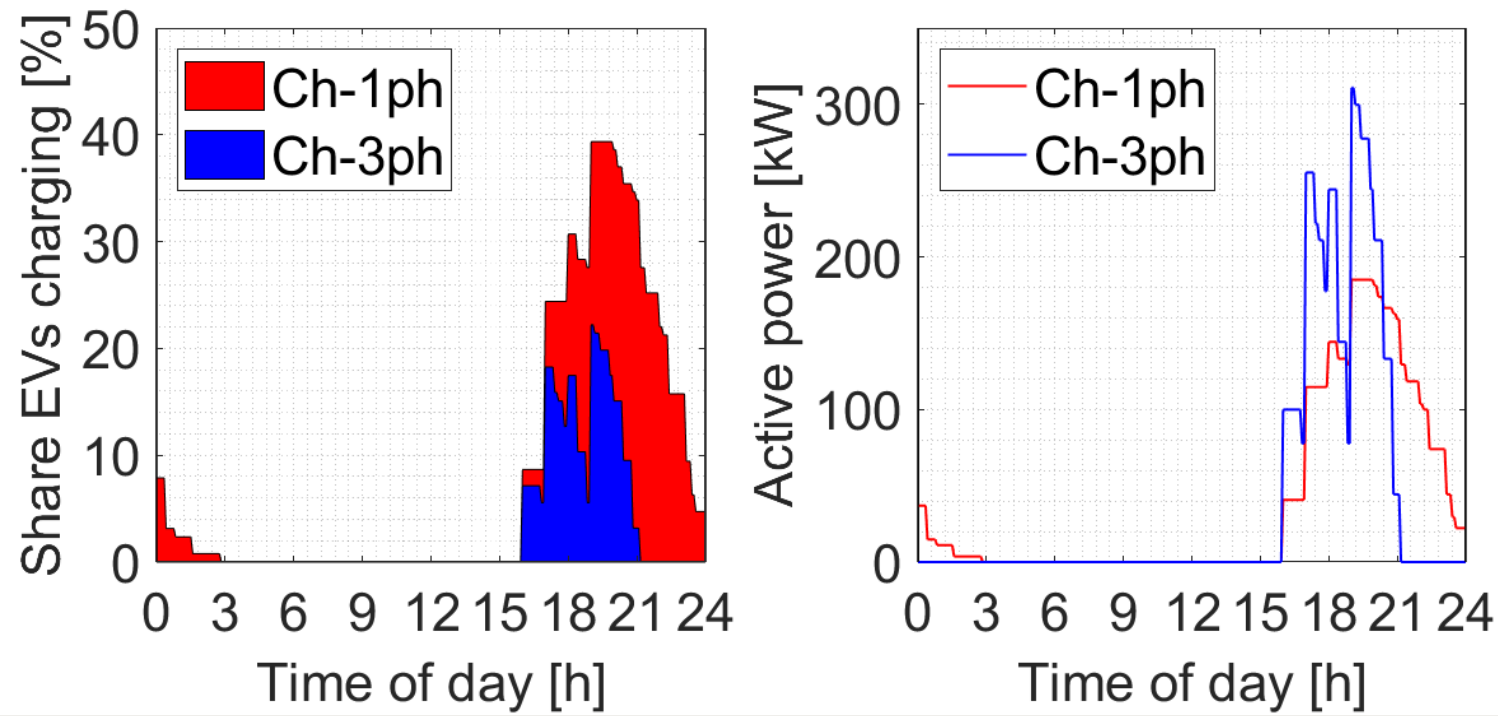


L. Calearo, A. Thingvad, K. Suzuki and M. Marinelli, "*Grid Loading Due to EV Charging Profiles Based on Pseudo-Real Driving Pattern and User Behavior*," in *IEEE Transactions on Transportation Electrification*, vol. 5, no. 3, pp. 683-694, Sept. 2019, doi: 10.1109/TTE.2019.2921854.

The local grid – the driving behaviour matters

Distribution feeder with ~127 households (representative feeder): 127 EVs (100% EV penetration)

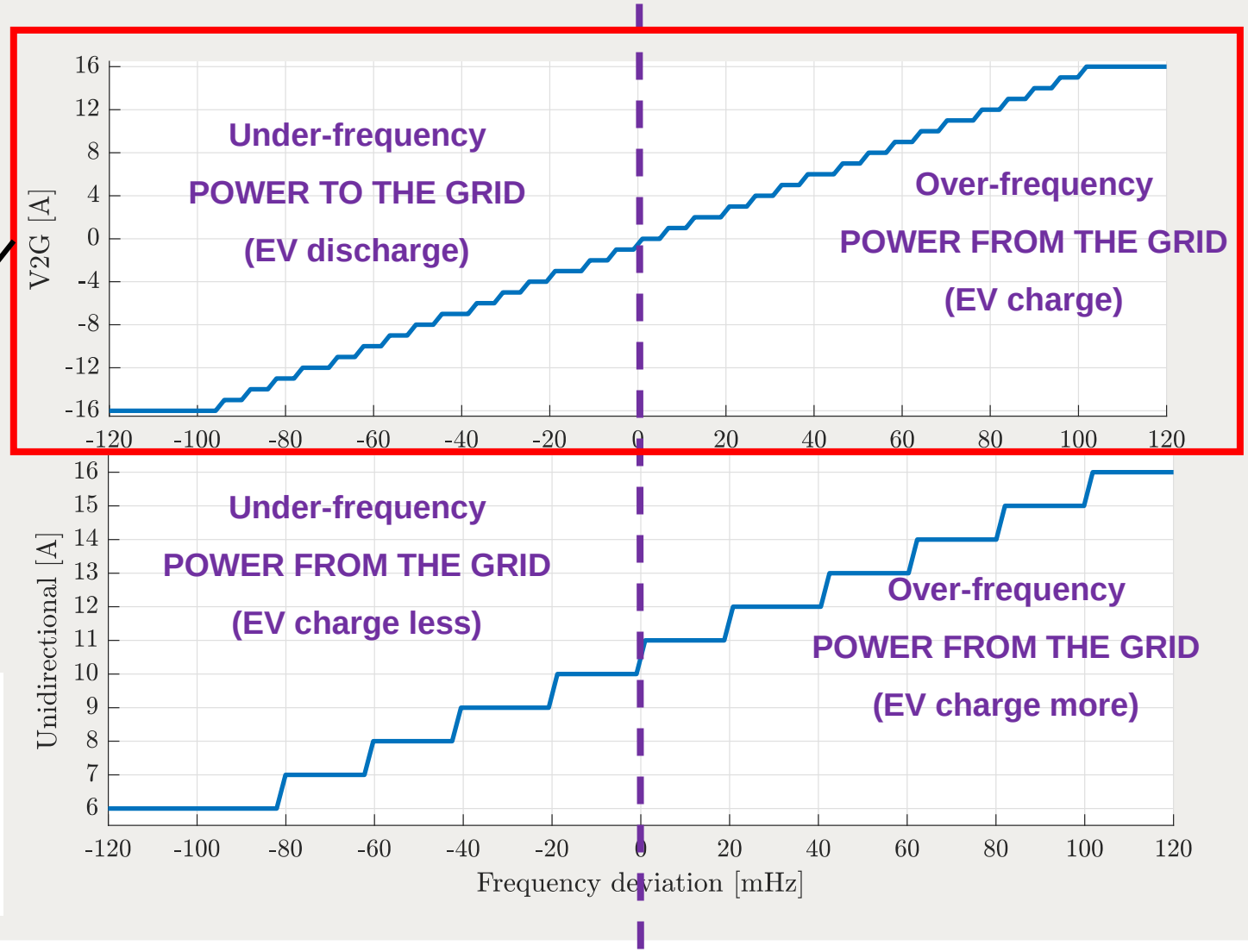
Ch-1ph: 3.7 kW
Ch-3ph: 11 kW



Primary Frequency Control – bidirectional (V2G) or unidirectional flow

- The frequency is the measurement of how much a system is (im)balanced
- Frequency control is realized via active power management

Revenue more than 1000 €/year → but profit heavily dependent on charger efficiency and market framework for energy metering.



V2G in Frederiksberg Forsyning: system configuration

- 10 Nissan env-200 – 24 kWh
- 14 hours
- ±9.2 kW

Aggregator

Grid Services
Energy to/from Electric Grid

Bi-directional
Energy Flow

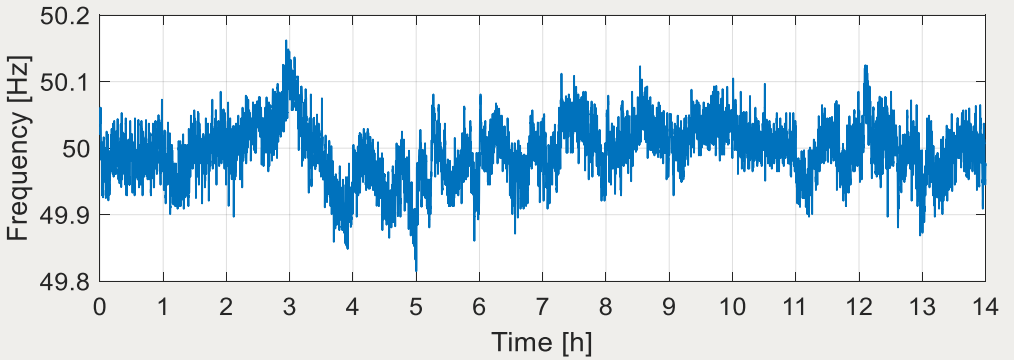
Distributed Energy
Storage

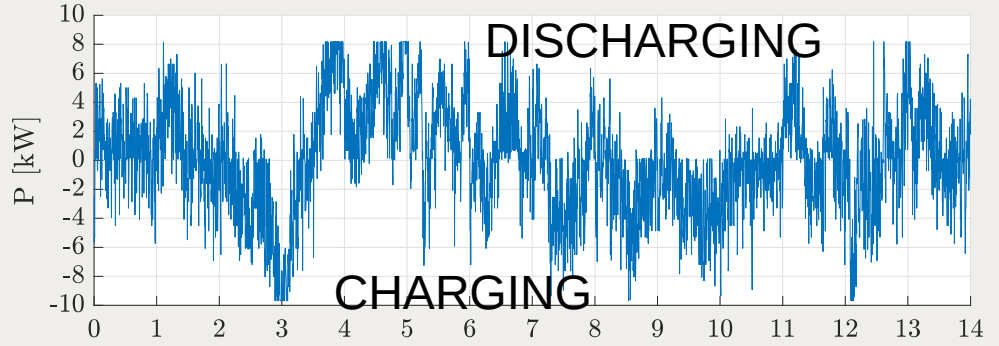
VSL Vehicle System Link Software – Software Defined Charging Station

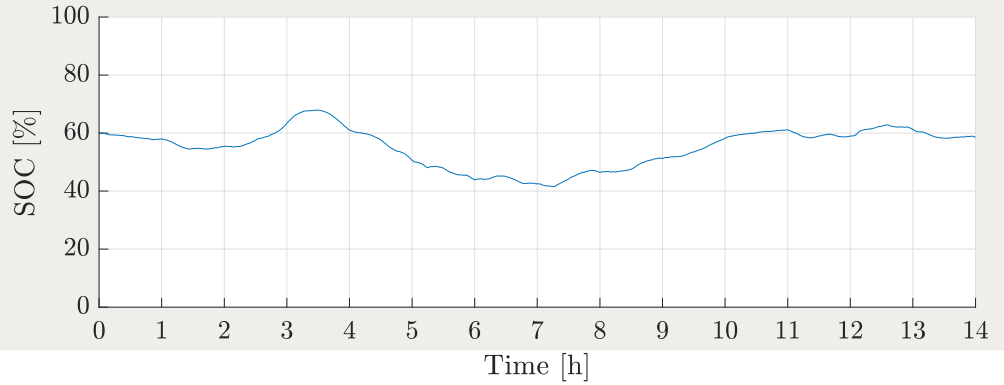
Control signals

Bi-directional energy flow

Bidirectional Frequency Regulation – V2G





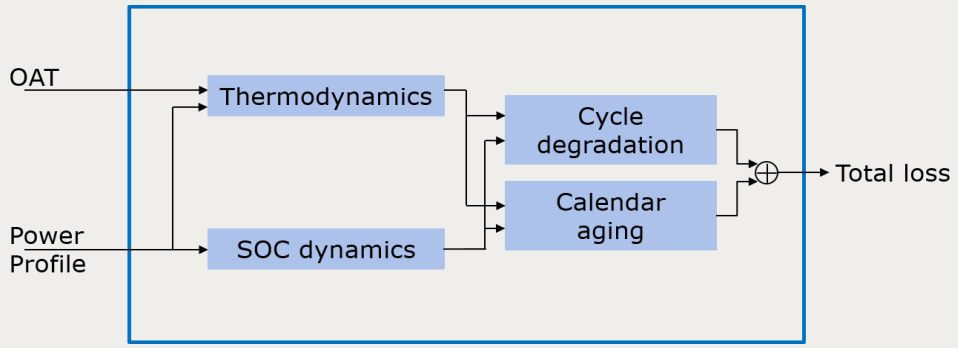


Assessing the impact in term of degradation – how much driving and V2G services affect battery lifetime

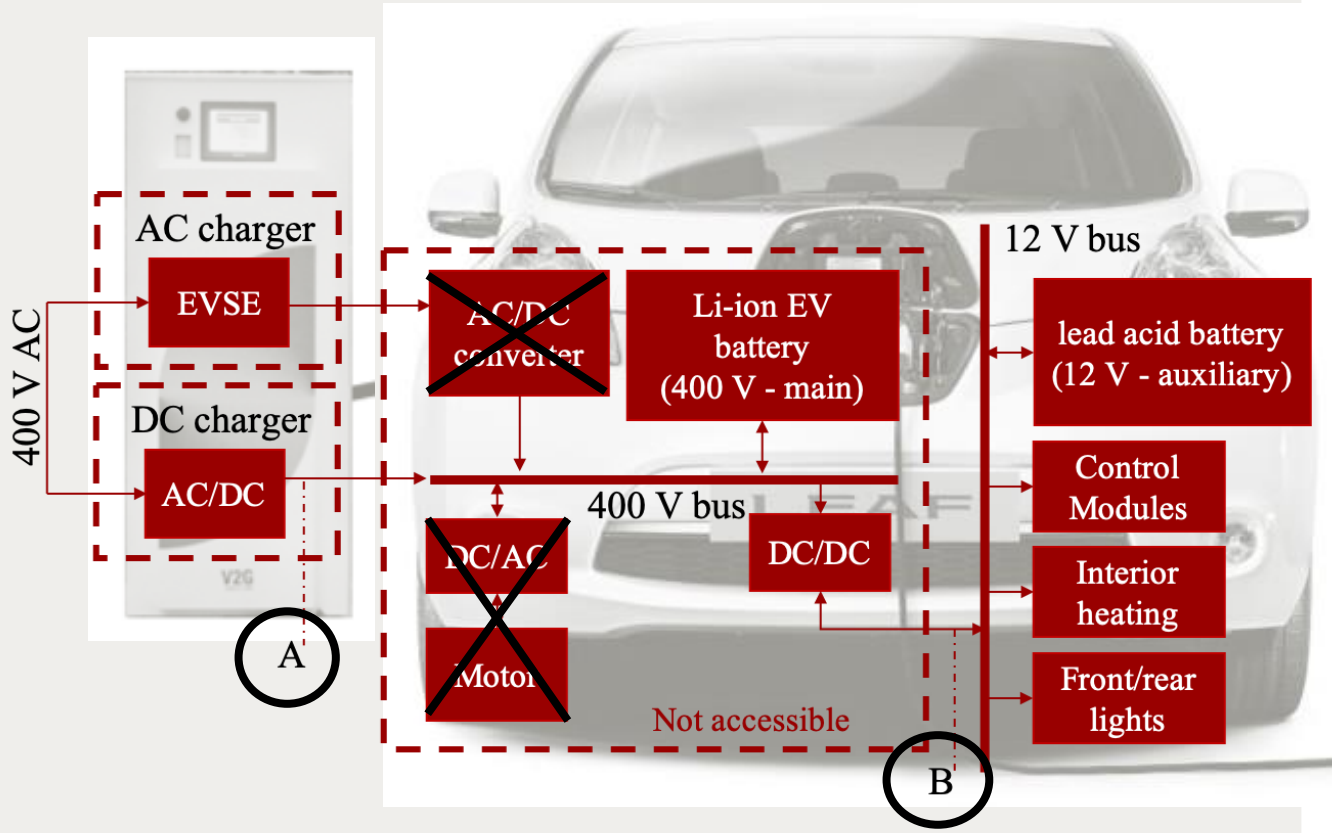
The model

Calendar degradation: SOC, battery temperature and time.

Cycle degradation: battery temperature, capacity and current.



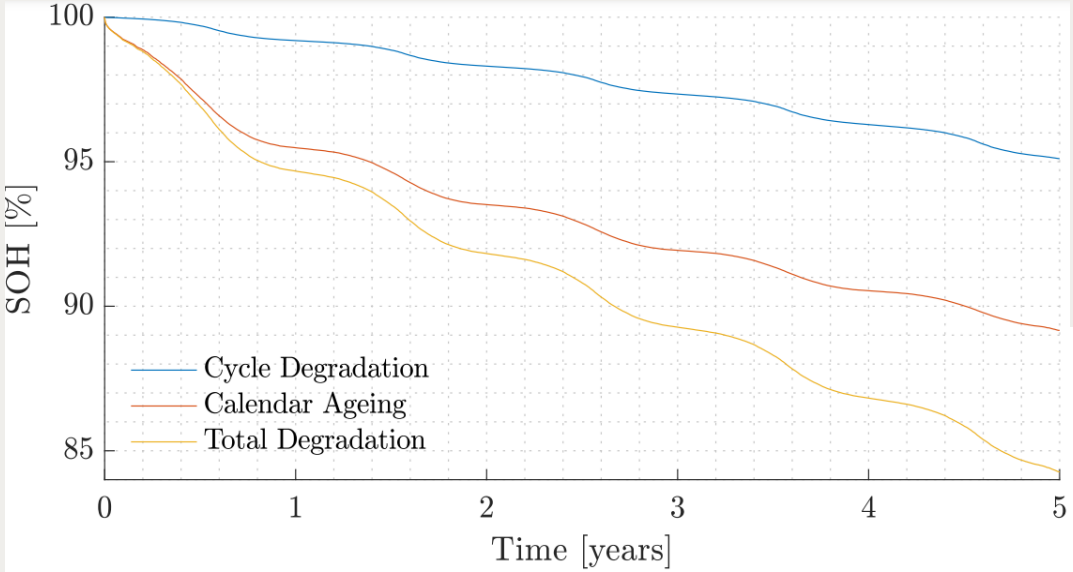
The measurements

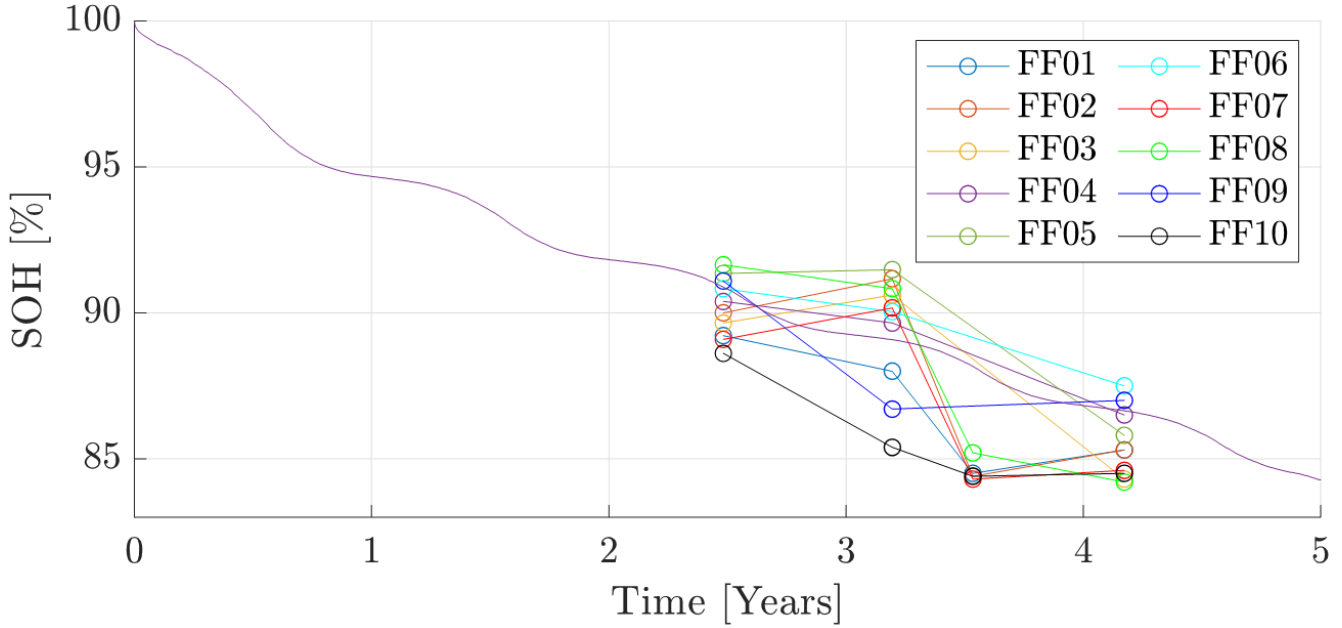


A. Thingvad & M. Marinelli, “Influence of V2G Frequency Services and Driving on Electric Vehicles Battery Degradation in the Danish Island Bornholm”, EVS31.
L. Calearo, A. Thingvad, M. Marinelli, “Modelling of Electric Vehicles for Degradation Studies,” Universities Power Engineering Conference (UPEC), 2019 Proceedings of the 54th International, pp. 1-6, Bucharest, 3 Sep. – 6 Sep. 2019.

Results from Frederiksberg Forsyning

10 Nissan env-200 (24 kWh): driving and frequency control





A. Thingvad, L. Calearo, P. B. Andersen, M. Marinelli, “Capacity Measurements of Electric Vehicle Battery Degradation from V2G services,” Under review.

Conclusion

- User behaviour is relevant to predict charging user choice and impact on local grids
- Frequency market can be remunerative, but need for extra equipment (V2G charger), cost of losses and need to fulfil bid requirements can reduce the profit.
- Additional wear due to the intense bidirectional power flow during grid provision (frequency control), amounts to only few additional percent compared to the natural degradation.

Future work

- Development of an autonomous smart charge (unidirectional) controller together with a distributed virtual aggregator (ACDC project: https://www.acdc-bornholm.eu/)
- Demonstration of DC microgrid consisting of reconfigurable BESS - PV System and EV ultra-fast chargers to reduce EV charging impact on the grid connection (INSULAE project: http://insulae-h2020.eu/)

References

- L. Calearo, A. Thingvad, K. Suzuki and M. Marinelli, "*Grid Loading Due to EV Charging Profiles Based on Pseudo-Real Driving Pattern and User Behavior*," in *IEEE Transactions on Transportation Electrification*, vol. 5, no. 3, pp. 683-694, Sept. 2019, doi: 10.1109/TTE.2019.2921854.
- A. Thingvad & M. Marinelli, “Influence of V2G Frequency Services and Driving on Electric Vehicles Battery Degradation in the Danish Island Bornholm”, EVS31.
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- A. Thingvad, L. Calearo, P. B. Andersen, M. Marinelli, “Capacity Measurements of Electric Vehicle Battery Degradation from V2G services,” Under review.
- R. Juul Askjær, P. B. Andersen, A. Thingvad, M. Marinelli, “*Demonstration of a Technology Neutral Control Architecture for Providing Frequency Control Using Unidirectional Charging of Electric Vehicles*,” UPEC 2020, Torino.
- J. Bollerslev, P. B. Andersen, T. V. Jensen, M. Marinelli, A. Thingvad, L. Calearo, T. Weckesser, “*Coincidence Factors for Domestic EV Charging from Natural Driving and Plug-in Behaviour”*, Under review.

For more information on the ACES project results:

- Marinelli, M., Thingvad, A., & Calearo, L. (2020). Across Continents Electric Vehicles Services Project: Final Report. DTU.
- ACES Project (aces-bornholm.eu)

Further research projects:

https://orbit.dtu.dk/en/persons/lisa-calearo

Thanks for your attention!

Questions?

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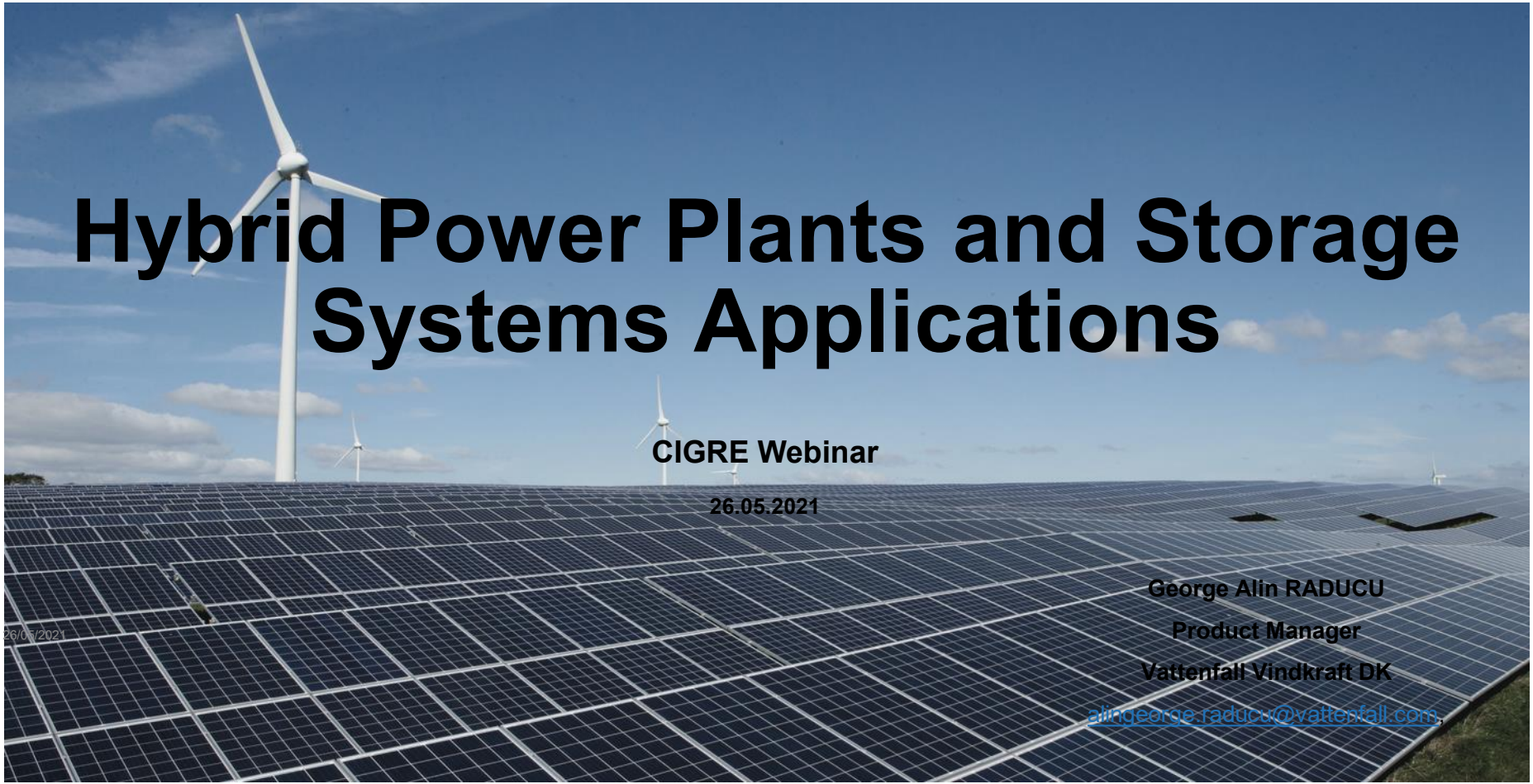


Hybrid Power Plants and Storage Systems Applications

CIGRE Webinar

26.05.2021

George Alin RADUCU

Product Manager

Vattenfall Vindkraft DK

alingeorge.raducu@vattenfall.com

Presentation Content

1. Vattenfall in Brief
2. Hybrid Power Systems at Vattenfall
3. Storage Systems Applications
4. Conclusions

Vattenfall in Brief

Key Facts / Figures

- One of Europe's leading energy companies
- 100% owned by the Swedish state
- Main products: electricity, heat, gas, energy services
- Main markets: Sweden, Germany, the Netherlands, UK, Denmark and Finland
- Electricity Production 2020: 112.8 TWh
- Net Sales 2020: 158,8 MSEK

VATTENFALL

6.8 million
Electricity customers

1.8 million
Heat customers

3.3 million
Electricity network customers

2.3 million
Gas customers

19,859
Employees

Activities in the value chain

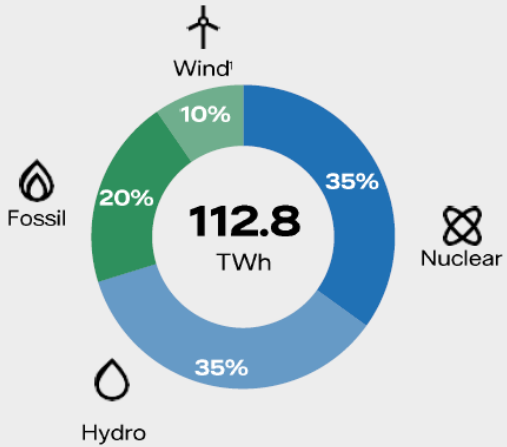
Active
Inactive

Upstream | Production | Transmission | Distribution | Trading | Retail | Services

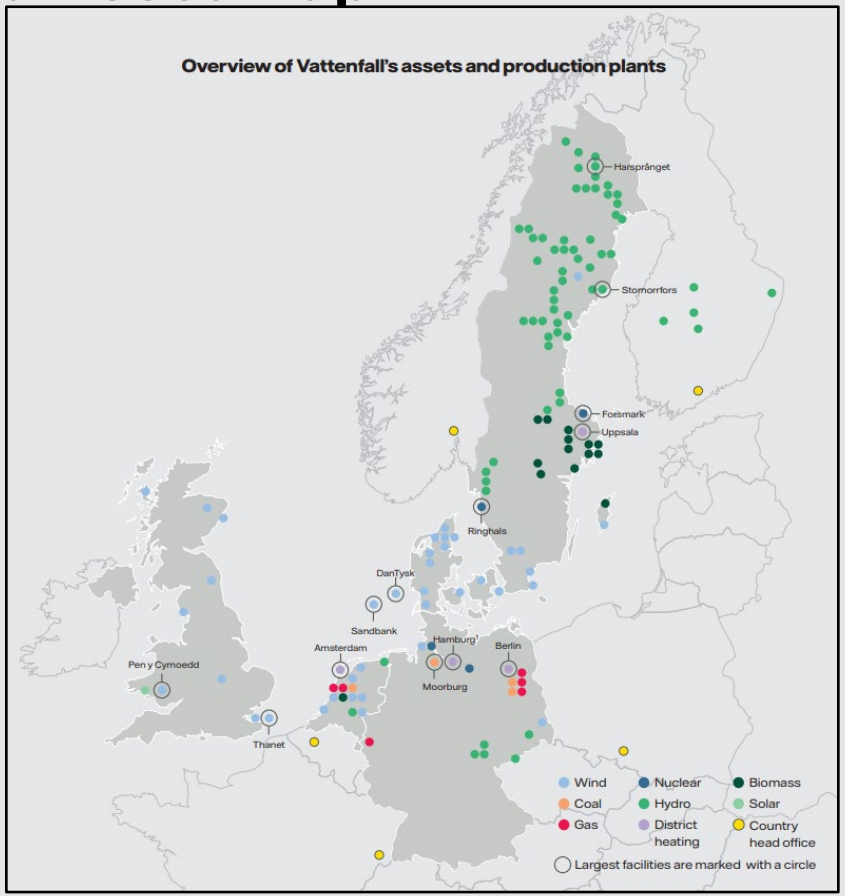
Electricity Generation and Asset Map

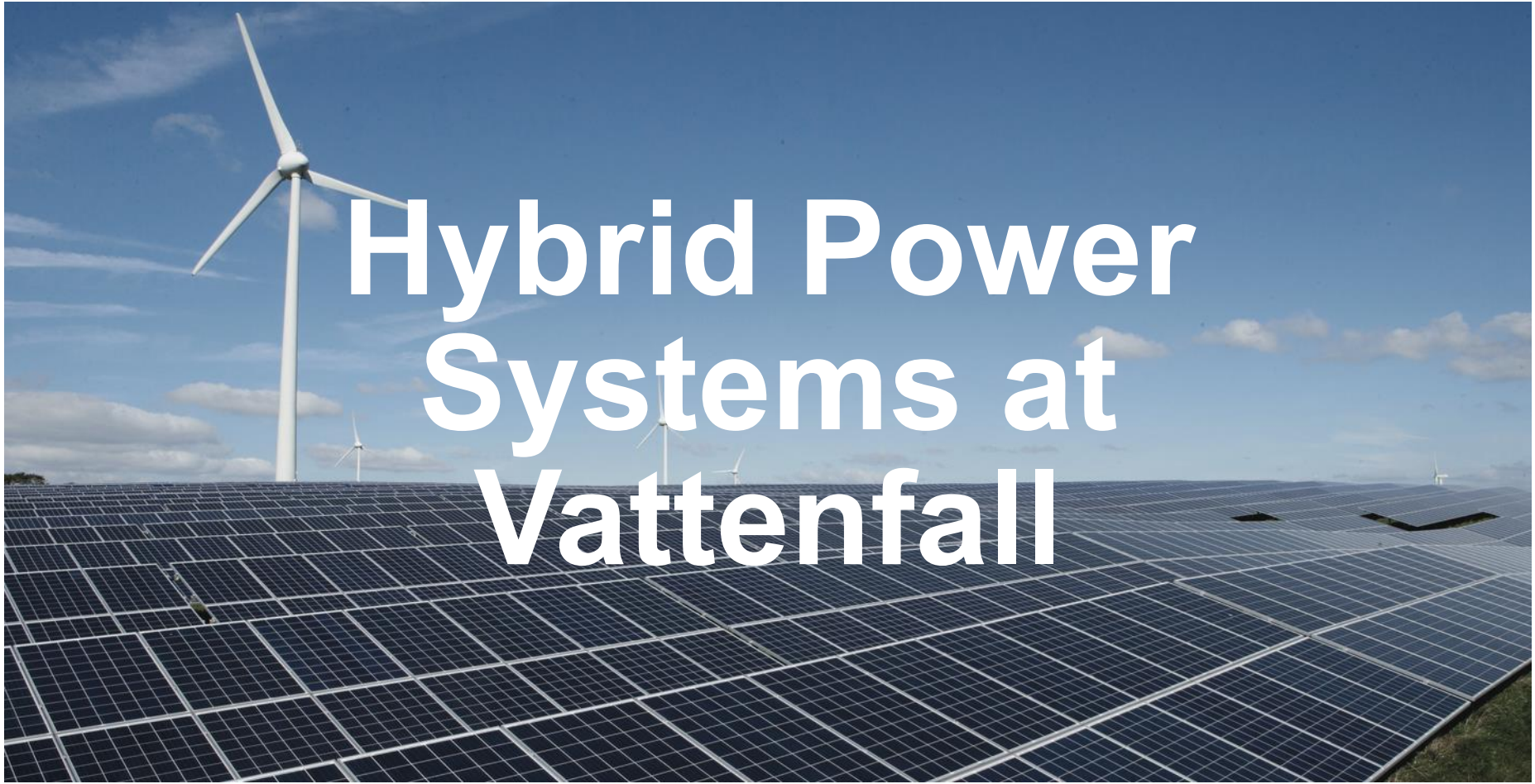
VATTENFALL

Electricity generation breakdown by technology, 2020



[1]Wind includes biomass and waste generation (0.3 TWh)





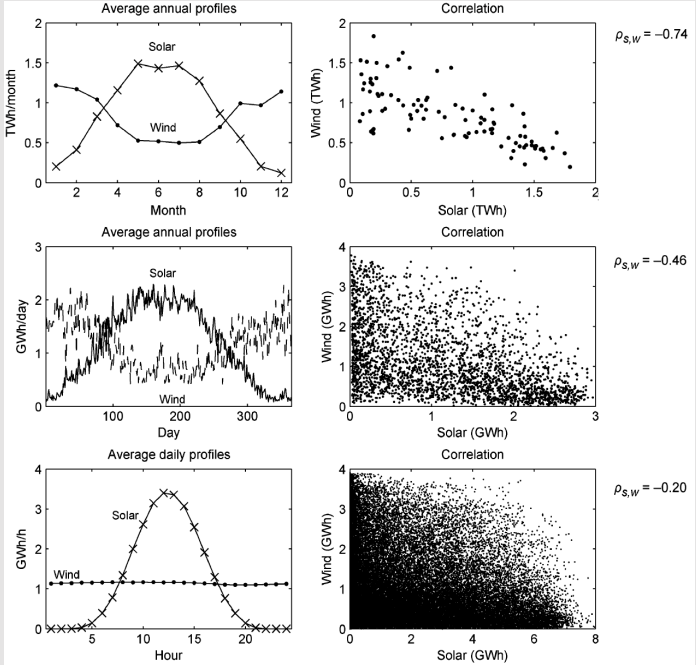
Hybrid Power Systems at Vattenfall

Background

- Vattenfall aims to be fossil-free within one generation
- Sweden committed by law to be carbon-neutral by 2045
- Result: Increased focus in renewables energy sources (Wind & Solar)
  - Investigating different storage and flexibility opportunities
- Challenges: Integration of the different technologies

Good correlation of wind and solar PV?

- Strong (negative) correlation of monthly wind and PV production in Northern Europe
- The stronger the negative correlation the better regarding e.g. utilization of the grid connection & balanced energy output
- Correlation decreases with shorter time spans
- Our experience at the hybrid plant Park Cynog:
  - Monthly correlation: -0,89
  - Daily correlation: -0,32
  - 10-Min correlation: -0,15
- Adding a battery would improve the 10-Min, Hourly and Daily correlation
- Dimensioning of the solar and wind capacity is very important



Advantages of Hybrid Power Plants

Co-location Solar & Wind

Decreased Project Costs

- Joint project development
- Joint use of infrastructure & land
- One grid connection point
- Higher overall project efficiency

Higher Grid Utilization

- Negative correlation between wind and solar generation
- Additional battery supports grid utilization even further
- Smoother feed-in profile compared to stand alone

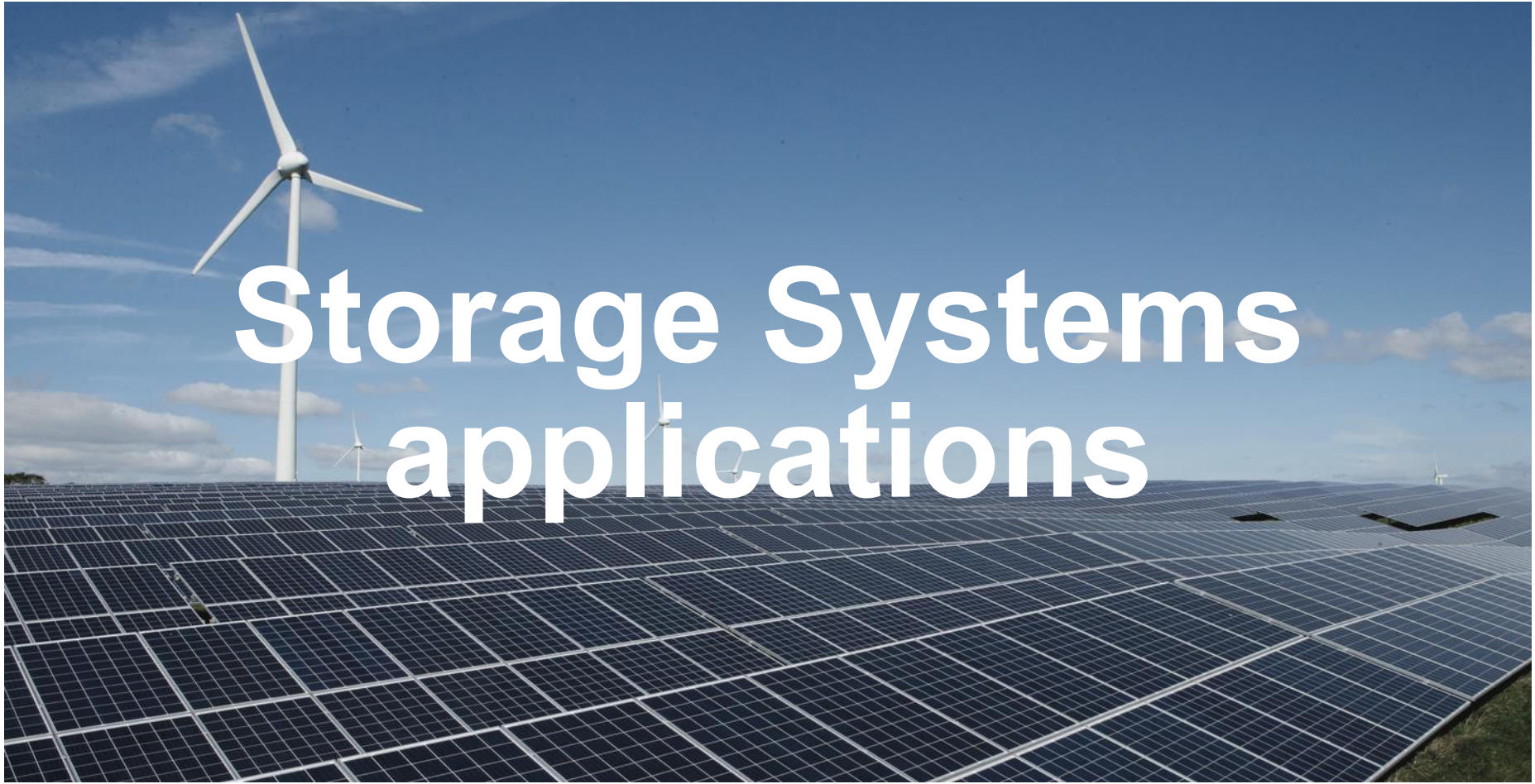
Renewable Farm & Battery Storage

Grid Support and Market Based Revenues

- Frequency Containment Reserve
- Automatic Frequency Restoration Reserve
- Reactive Power Support (near future)
- Black Start Capability (future)
- Imbalance Trading
- Arbitrage Market

Internal Park Optimization

- Self-consumption optimization (internal HPP production peak shaving)
- Backup capacity (during outages)
- Reduced impact of the Day Ahead forecasting errors
- PCC sizing optimization (Modeling Assignment)
- Curtailment Optimization (Modeling Assignment)


Storage Systems
applications

Developing and operating commercial battery projects

Home battery storage systems

Medium size

Large size

3 Main Categories

Own & Operate

Applications of battery storage

Renewable firming
Firm up renewable generation by reconciling the intermittency of power and storing excess capacity

Grid Investment Deferral
Supply power or energy capacity at a distributed location to defer the need to upgrade grid infrastructure.

Ancillary Services
Sell services to grid operators e.g. frequency control, reactive power control

Self Consumption (Solar)
Maximise consumption of fossil free power generated on site

Uninterruptible Power Supply
Provide back up power in the event of grid outages excess capacity

Peak Shaving (C&I)
Reduce power peaks on demand side, reducing costs for energy and grid connection.

Energy Shifting
Charge of battery during low demand (low spot prices), discharge during high demands (high spot prices).

Temporary Power Supply
Provide power or energy capacity in a location with no or limited supply of power as an alternative to diesel generators or additional grid connection

Battery@Alexia

Project	Alexia Wind Park
Location	Netherlands
Power/Energy	3.2 MW / 3 MWh
Application	Primary Frequency Control
Secondary Application	Imbalance Trading
Operational	2017
Batteries	BMW, SE07, Liquid Cooled

Battery@PyC

Project	Pen-y-Cymoedd (PyC)
Location	United Kingdom
Power/Energy	22 MW / 15 MWh
Application	Enhanced Frequency Response
Secondary Application	Capacity Market
Operational	2018
Batteries	BME, 470 x SE07, Liquid Cooled

Battery@Haringvliet

Project	Haringvliet Wind Park
Location	Netherlands
Power/Energy	12 MW / 12 MWh
Application	Primary Frequency Control
Secondary Application	Imbalance Trading
Operational	2021
Batteries	BMW, 280 x SE09, Liquid Cooled

Battery@Jungheinrich

Project	Jungheinrich
Location	Germany
Power/Energy	0.3 MW / 0.3 MWh
Application	Peak Shaving
Secondary Application	-
Operational	2016
Batteries	BMW, SE07

Battery@Ingredion

Project	Ingredion
Location	Germany
Power/Energy	0.5 MW / 1.0 MWh
Application	Peak Shaving
Secondary Application	-
Operational	January 2020
Batteries	BMW, SE09, Liquid Cooled

Battery@Amsterdam

Visualization

Project	Amsterdam Fast Charging
Customer	Municipality of Amsterdam
Location	Netherlands
Power/Energy	0.24 MW / 0.34 MWh
Application	Grid Investment Deferral
Secondary Application	Peak Shaving
Operational	2019
Batteries	BMW, SE09

Battery@Uppsala

Project	Uppsala
Customer	Network Solutions
Location	Sweden
Power/Energy	5 MW / 20 MWh
Application	Grid Deferral
Secondary Application	FCR-D, FFR
Operational	2021
Batteries	BMW, 480x SE09, Air cooled

Battery@Åre

Project	Åre
Customer	Network Solutions
Location	Sweden
Power/Energy	0.24 MW / 0.34 MWh
Application	Temporary Power for EV Charging
Secondary Application	n/a
Operational	2019
BMW	BMW, SE09

GreenBattery

Is the **green and sustainable** alternative to smelly diesel generators

Charged by **solar and wind** energy. Reliable, quiet, clean, sustainable and affordable alternative for diesel generators

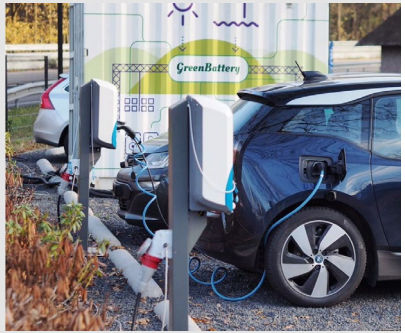
The system is extremely suitable for **environmental zones** and can even be **used indoors**

In addition, the battery supplies **power on demand** and does not need to be "started up“

Has a **sustainable appearance** by using the solar box

Has already **proven** that it is a perfect replacement for the old-fashioned diesel generator

Hardware is **multi-functional**, can move across markets and geographies for return maximization




Conclusions

Main Takeaways

Battery storage it is and will become more important with increasing penetration of fluctuating renewable energy sources

Batteries contribute significant to various applications in the energy market & create additional revenue streams

Stacking of applications is required in order to realize commercially feasible projects

Hybrid parks bring cost & revenue synergies compared to stand alone wind, solar parks or battery systems

Combining different technologies comes with new challenges (planning timelines, construction)

More regulatory improvements are required to support full integration of hybrid farms


Thank you for
your attention!

Welcome to the webinar: The Future Power System with Integrated Energy Storage

Time for Q&A

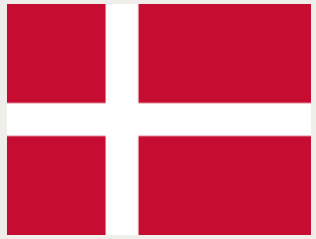


Image source: Siemens
(https://new.siemens.com/global/en/products/buildings/fire-safety/applications/li-ion-battery-storage-system.html)