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Lithium-ion Batteries for providing Virtual Inertia

Presenter:
Lennart Beushausen

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Agenda

- Motivation
- Ancillary services
- Research Project - ReserveBatt
- Virtual Synchronous Machine
- Virtual inertia response of a multi VISMA system
- Battery requirements
- Experimental results of the battery
- Summary and further steps of the project

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Motivation

- Providing power and inertia
  - stable power supply
  - equilibrium
- Decrease of conventional power plants
- Inertia is especially used for <u>damping</u> fast frequency changes

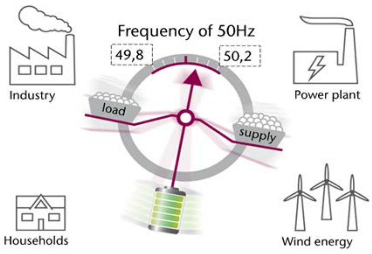

Fig.1: Physical effect and general functionality of the synthetic inertia in the frequency response

- Virtual inertia with inverters provided by high power batteries

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Ancillary services

Fundamental differentiation from ancillary services in frequency stability

1. Proportional power to the frequency gradient:

– rotating mass → provide inertia for damping the <u>initial</u> frequency change

– P~df/dt

– D controller

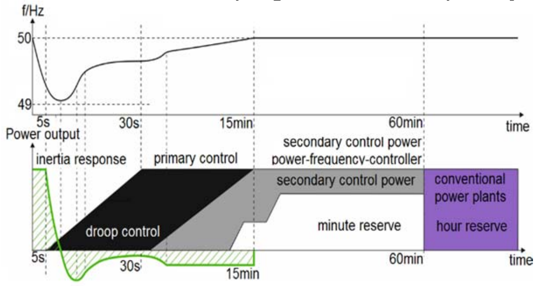

Fig.2: Effect and arrangement of the instantaneous reserve in the frequency response [1]

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Ancillary services

Fundamental differentiation from ancillary services in frequency stability

2. Proportional power to the frequency deviation:

– primary (black) and long term stability mechanism

– P~Δf

– P controller

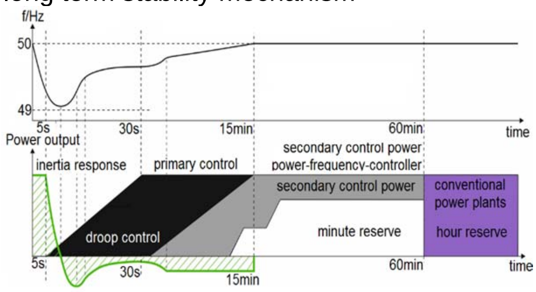

Fig.2: Effect and arrangement of the instantaneous reserve in the frequency response [1]

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Research Project - ReserveBatt

- 400 kVA battery-inverter demonstrator
- VSG algorithm
  "Virtual Synchronous Machine (VISMA)"
- Battery substitutes the energy of rotating masses
- Design and evaluation of utilization options and future business models

Virtual Synchronous Machine (VISMA)

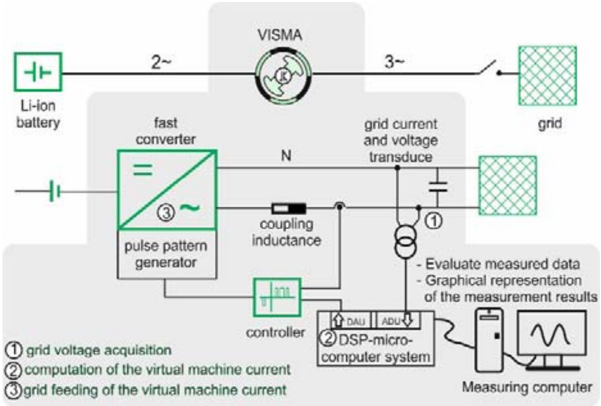

Fig.3: Fundamental set-up of the Virtual Synchronous Machine [2]

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Virtual inertia response of a multi VISMA system

- Response of VISMA system on frequency drop

H=E/S

H - inertia constant
E - kinetic energy of the generator turbine system
S - rated apparent power

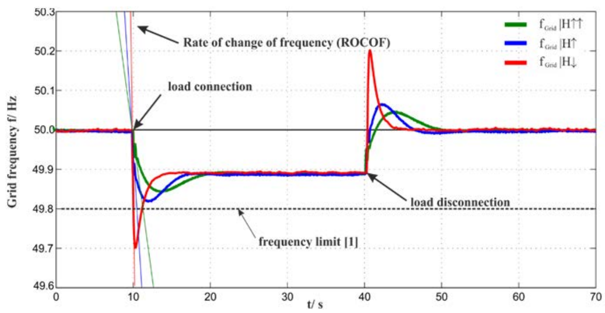


Fig.4: Frequency response for three different experimental setups [4]

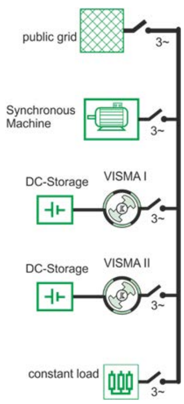
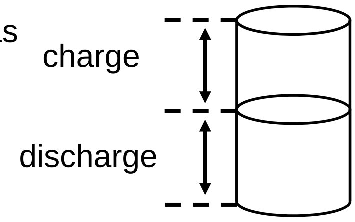


Fig.5: Circuit diagram of laboratory setup

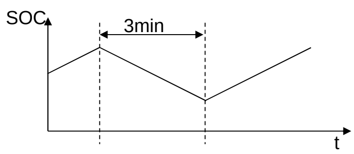
Battery requirements

- High frequency changes → fast power response
- Economical aspects → small batteries
  → High current rates
- Necessity to charge as well as to discharge
  → operating range around 50% State of Charge



General battery aging measurements

- Measurements with LFP batteries
- Different SOCs and DOD ranges



Equivalent Full Cycles,
40°C ,current rate of 2C

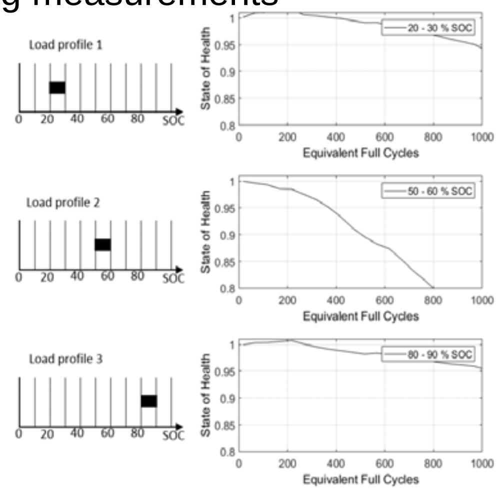


Fig.6: Battery aging measurements of LFP batteries

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General battery aging measurements

- Measurements with NMC batteries
- Different SOCs and DOD ranges

Equivalent Full Cycles, 30°C ,current rate of 1C

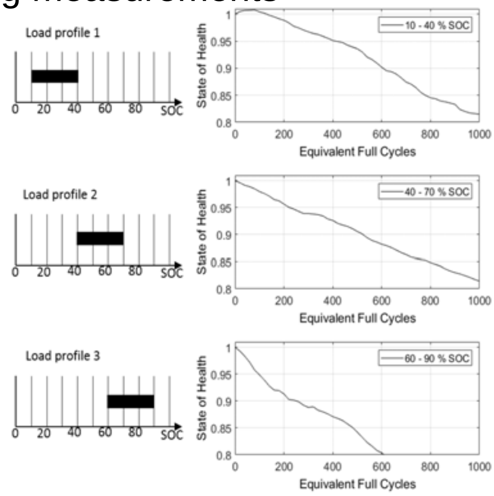

Fig.7: Battery aging measurements of NMC batteries

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Summary and further steps of the project

- LFP batteries probably not good to use around 50% SOC → NMC
- Economic usage of li-ion batteries for ancillary services are strongly dependent on their application

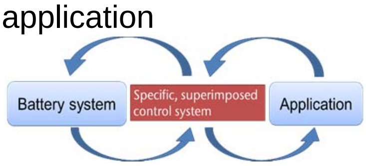

Fig.8: Schematic of superimposed control system

- Grid simulation ⟷ longer measurement periods
- Power profiles ⟷ simulations and aging measurements
- Power plant performance 400kVA inverter

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Thank you for your attention!

- Patent:

H.P.-Beck et al., Konditionierungseinrichtung für Energieversorgungsnetze, Patent EP2070174B1, 2007

- Literature:

[1] H.-P. Beck et all: Technische Mindesterzeugung des Kraftwerksparks bis zum Jahr 2030 in Niedersachsen und Deutschland, ISBN 978-3-7369-9626-7, Cuvillier, Goslar 2017

[2] Y. Chen, Virtuelle Synchronmaschine (VISMA) zur Erbringung von Systemdienstleistungen in verschiedenen Netzbetriebsarten, Cuvillier, 2016

[3] R. Benger, L. Beushausen, H. Wenzl, H.-P. Beck: Aging of lithium-ion batteries in high dynamic applications, Kraftwerk Batterie, 26.-27. April 2016, Münster

[4] Y. Chen, R. Hesse, D. Turschner und H.-P. Beck, Improving the grid power quality using virtual synchronous machines, 2011 International Conference on Power Engineering, Energy and Electrical Drives (POWERENG), S. 1–6, 2011

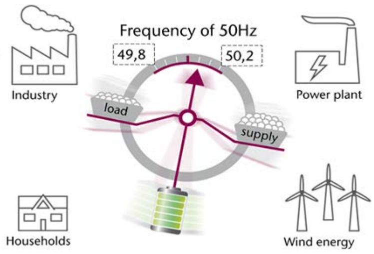

Fig.1: Physical effect and general functionality of the synthetic inertia in the frequency response

- Further literature is deposited in the full paper

Contact:
M.Sc. Lennart Beushausen
Lennart.beushausen@tu-clausthal.de
tel.: +49 5321/3816-8065

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Grid analyses

- Load Profile stochastics for the virtual synchronous generator
- Simulation from measurements
- Possible loads on a battery system
- 400kVA converter system

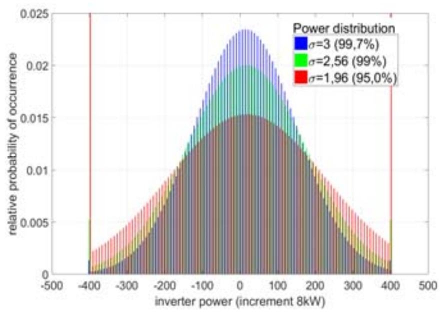

Fig.1: Possible loads on a battery system when providing virtual inertia with the VISMA and a 400kVA converter system (based on intern data of the Tennet GmbH).