Agenda

- APG Mission 2030, rapid expansion of renewable energies
- Stage I: Digital twin of transformer
- Stage II: Overload capability of transformers in SCADA and Network Applications
- Stage III: Active Digital Load Management for Transformers
Europe is electrifying and electricity is decarbonizing

**UK:**
- wind: 21 GW
- PV: 13 GW

**DK:**
- 50 % renewable-share of primary energy mix by 2030

**NL:**
- carbon floor price from 2020
- nuclear phase-out by 2025?
- 11.5 GW offshore wind by 2030

**FR:**
- wind: 15 GW
- PV: 9 GW

**DE:**
- wind: 59 GW
- PV: 46 GW
- renewable share 65 % by 2030 (electricity) → massive PV & wind expansion
- nuclear phase-out (by 2022)
- coal phase-out (by 2038)

**AT:**
- 100 % renewable by 2030 (electricity sector)
- massive PV & wind expansion

**IT:**
- wind: 10 GW
- PV: 20 GW
- coal phase-out (2025-2030)

**ES:**
- wind: 24 GW
- PV: 8 GW
- PV plant without subsidy (170 MW)

Source: installed capacities (Platts 12.04.2019)
Austria is on its way towards 100% renewables in the electricity sector.

**Renewable share:**
- Run of river: ~ 5,700 MW
- Hydro storage: ~ 8,800 MW
- Pumps: ~ 4,200 MW

**2030:** electricity sector
**2050:** full decarbonization

- **2018:**
  - Wind: 3,0 GW
  - PV: 1,4 GW

- **2018:** x 4

**Notes:**
- *) 2018 Netzbetreiberumfrage laut E-Control / Stand: 15.11.2018
In 2018 full load coverage from renewables was not yet possible.
Rising transport volumes\(^{(1)}\) emphasize increasing importance of the transmission grid.

\(^{(1)}\) Transport volumes in the transmission grid of APG (380-kV and 220-kV)
Lacking transmission grid led to increasing emergency measures

### Year 2018

| Month   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Jänner  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| Februar | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |    |
| März    | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |    |
| April   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |    |
| Mai     | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |    |
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| August  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |    |
| September| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |    |
| Oktober | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |    |
| November| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |    |
| Dezember| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |    |

### Days with emergency measures in 2018

- 282 days in 2018

### Costs in DE:
- 2017: 1.5 bil. EUR
- 2018: 1.4 bil. EUR

### Costs in AT

Transmission grid cannot fulfil market demand → costly emergency measures needed...
- 2017: 92 Mio. EUR
- 2018: 117 Mio. EUR
- monthly ~ 10 Mio. EUR (borne by Austrian electricity customers)
Austria’s way to 100% renewables has just begun …

- **2018**
  - Wind: 3.0 GW
  - PV: 1.4 GW

- Renewable share: ~70% → 100%
Austria’s way to 100% renewables has just begun ...

Renewable share:

2018
Wind: 3,0 GW
PV: 1,4 GW

2030
100 %

70 %
Austria’s way to 100% renewables has just begun...

2008

2018

2030

Wind: 3,0 GW
PV: 1,4 GW

Renewable share: ~ 70 %

2030

Wind: 9 GW
PV: 12 GW

100 %

(1) Quelle: „Stromzukunft Österreich 2030 – Analyse der Erfordernisse und Konsequenzen eines ambitionierten Ausbaus erneuerbarer Energien“; TU Wien; Mai 2017
Outlook 2030: 100 % renewables in the electricity sector

Assumption installed capacity:
- PV: 12 GW
- Wind: 9 GW

*) average of weekly minimum and maximum (weather year 2018)
100 % renewables lead to new challenges …

1. Extreme $\frac{1}{4}$ h gradients
2. Balance day / night
3. Seasonal shift

*) average of weekly minimum and maximum (weather year 2018)

10 GW surplus
100 % renewables lead to new challenges...

1. Extreme ¼ h gradients („peaks“)
2. Balance day / night
3. Seasonal shift

*) average of weekly minimum and maximum
(weather year 2018)

6 GW gap

~ 6 TWh in Q1
Decarbonization of the energy system implies increased electricity consumption …

- Industry (e.g.: steel production)
- E-Mobility
- Digitalization (e.g.: data centers, blockchain)
- Heat pumps, …

Outlook 2050\(^{(3)}\):
- Wind: 24 GW (x 8 to 2018)
- PV: 32 GW (x 25 to 2018)
Succeeding in the transformation of the energy system requires a broad set of flexibility options ...

Grid extension is (today) the most efficient and cheapest flexibility option.
How to ensure grid security?

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Loading</th>
<th>Scenario</th>
</tr>
</thead>
<tbody>
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<td>Szenario 2</td>
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<tr>
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<td>Szenario 4</td>
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</table>

Redispatch / curtailment

Push the limits of the grid
- Thermal rating for lines
- Digital Load Management for Transformers
Redispatch & curtailment

50Hertz (DE) remedial costs

- Efficiency- and cost-optimised planning of remedial actions
- Support of redispatch actions and curtailment of renewables
- Management and tracking of remedial actions

Siemens solution: Remedial Action Dispatching System (RADS)

DE in 2018
- 6 TWh curtailment of renewables
- € 800 million curtailment compensation for Wind+PV
- € 1.4 billion total costs of remedial actions

Source: https://www.50hertz.com/Portals/1/Dokumente/Medien/Pressemitteilungen/20190226_Bilanzpresskonferenz_2018.pdf (17.06.2019)
How to ensure grid security?

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Redispatch / curtailment

Push the limits of the grid

- Thermal rating for lines
- Digital Load Management for Transformers
Create digital twin: Add sensors

- Cooling temperature
- Top oil temperature
- Trafo cabinet control
- Flow monitoring
- Bottom oil temperature
- Outside temperature
- Monitoring control cabinet
- Cooling exit temperature
- Radiator temperature
- Wind and rain sensor
Create digital twin: Refine simulation

- Refined understanding of
  - the actual overload capability
  - the short & mid term overload capability
  - the effects of active cooling
  ➢ Efficient use of the capabilities of the transformers
Integration of the transformer load management in the control center

SITRAM® TDCM = Transformer Diagnostic and Condition Monitoring

Integrated Siemens Systems
Overload capability in SCADA and RT Network Applications

1. Overload capability from digital twin
   • Based on measurements and refined simulation model

2. Spectrum Power SCADA + NA RT
   • Violation checks in SCADA
   • Network Applications: SE, PF, CA, OPF, SCS

3. Reduction of redispatch costs
   • Fewer violations
   • Lower redispatch / curtailment costs
Overload capability in forecast calculations

1. Overload capability forecast
   - Based on weather forecast and simulation

2. Spectrum Power congestion forecast
   - IDCF, DACF, D2CF*

3. Reduction of redispatch costs
   - Fewer violations
   - Lower redispatch / curtailment costs

* IDCF = Intraday Congestion Forecast
  DACF = Day Ahead Congestion Forecast
  D2CF = 2 Day Ahead Congestion Forecast
When the capability forecast is not sufficient

1. Overload capability forecast
2. Spectrum Power congestion forecast
3. \((N-1)\)-violation!

- Load forecast
- Overload capability w/o pre-cooling

Graph showing the comparison of load forecast and overload capability over time from 14:00 to 16:15.
Active Digital Load Management for Transformers

1. Overload capability forecast
2. Spectrum Power congestion forecast
3. No redispatch required

Pre-cooling, optimization

- No redispatch/curtailment necessary
- Lower redispatch costs

Overload capability curves

Change to maximal cooling
No change of cooling

Overload Time in min

Load forecast
Overload capability w/o pre-cooling
Overload capability w/ pre-cooling

Pre-cooling
Summary

Support of APG Mission 2030 by Siemens

Stage I
Digital twin of transformer
- Data collection and analysis
- Implementation

Started in 2018

Stage II
Overload capability in SCADA, NA
- Define connection to SCADA system

In preparation

Stage III
Digital Load Management for Transformers

Concept phase
Thank you!

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