SIEMENS

Ingenuity for life

APG

AUSTRIAN POWER GRID

STROM BEWEGT

OPTIMISATION OF LOAD FLOW, AVAILABILITY AND STABILITY IN THE TRANSMISSION GRID WITH PHASE SHIFTING TRANSFORMERS

Purpose & function of phase shifting transformers

- Phase shifting transformers are used for a (better) control of power flows in complex power grid to
  - avoid overloading of power transmission lines or components
  - increase the availability of electrical power
  - keep the committed power transfer at network node
- Phase shifters creates a phase shifting between the primary (source) and secondary (load) side
- Phase shifting can be done in advance or retard operation

Categories and types of PSTs

- symmetrical – asymmetrical
- quadrature – no quadrature
- one active part – two active parts
- one tank – two tanks

$$P_{RD} = P_T \text{ x } 2 \text{ x } \sin(\alpha_0/2)$$

P_T … throughput power

P_{RD} … rated design power

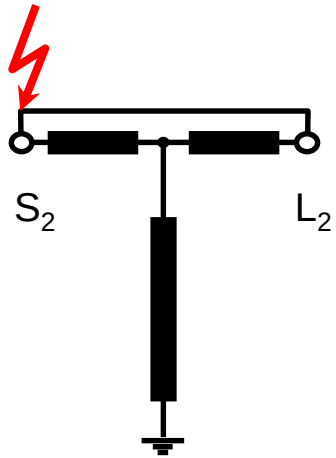
α_0 … no-load phase angle

PST special considerations for testing

Due to the complexity of PSTs and to get similar operation conditions we recommend:

- PST fully assembled and connected like in service
- Heat run test with
  - minimized deviation of loss distribution
  - access to all windings for resistance measurement
- Induced voltage test at
  - zero and maximum phase shift
- Special Lightning Impulse (LI) Test if by-pass breaker is provided

Special by-passed LI Test



Operational considerations for PSTs

- Impedance as low as possible, minimum value determined by short circuit requirements
- Load flow reduced by impedance of PST at zero phase angle – minimum advanced phase angle of bypass to restore original load flow condition
- Overexcitation at retard operation
- Parallel operation – on-load tap changers doesn‘t switch exactly at same time – circulating currents!
- Control and protection of PSTs

APG at a glance

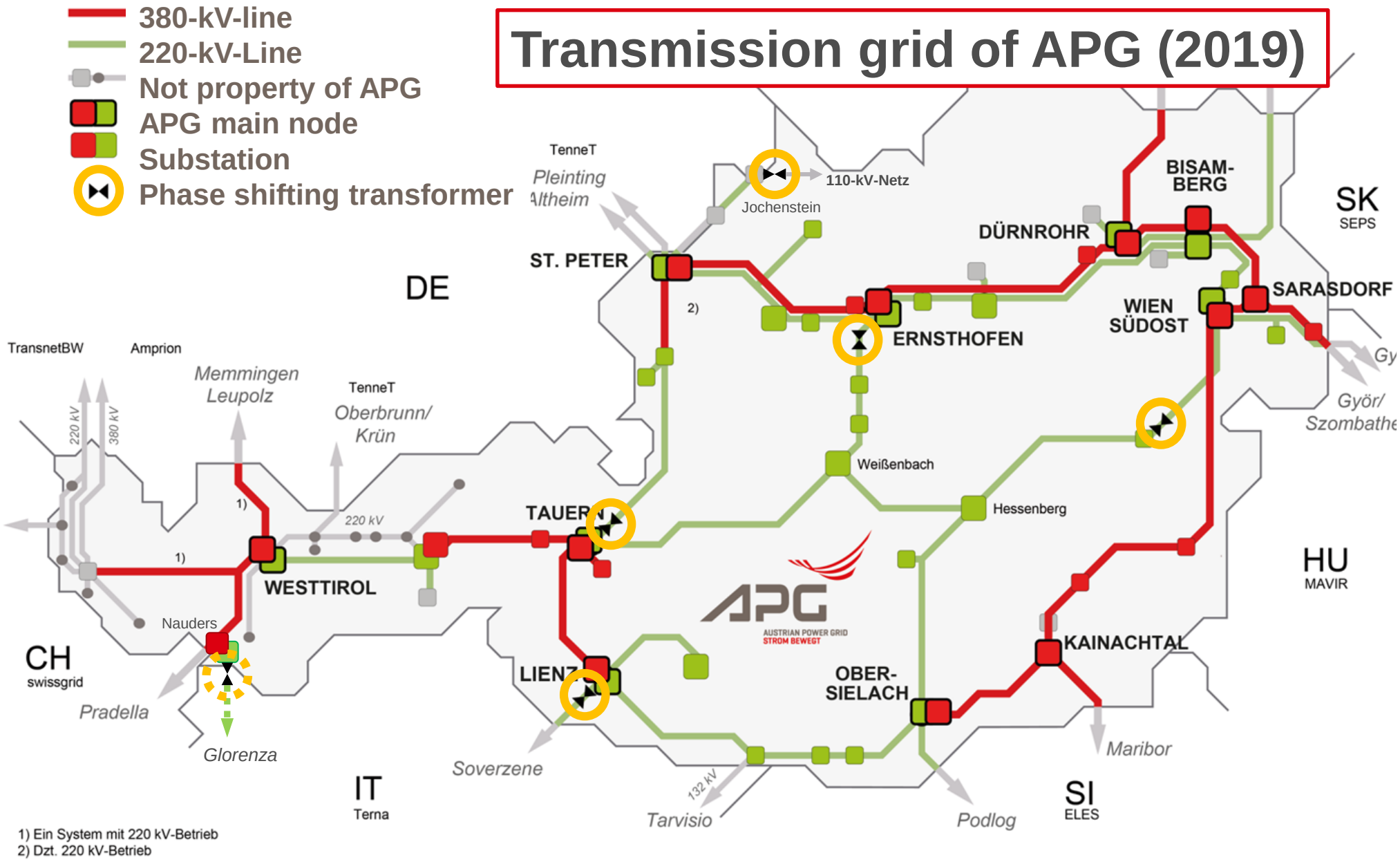
- **Transmission System Operator of Austria**

- **6.970 circuit-km**
  - 380 kV: 2.583 km
  - 220 kV: 3.206 km
  - 110 kV: 1.181 km

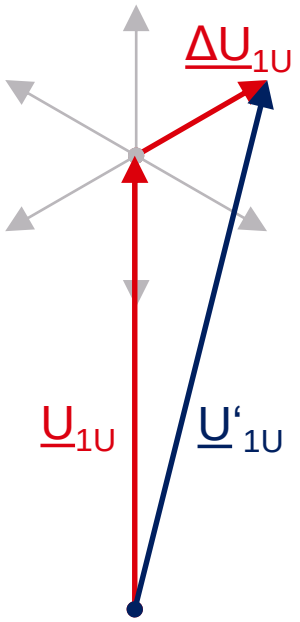
- **64 Substations**

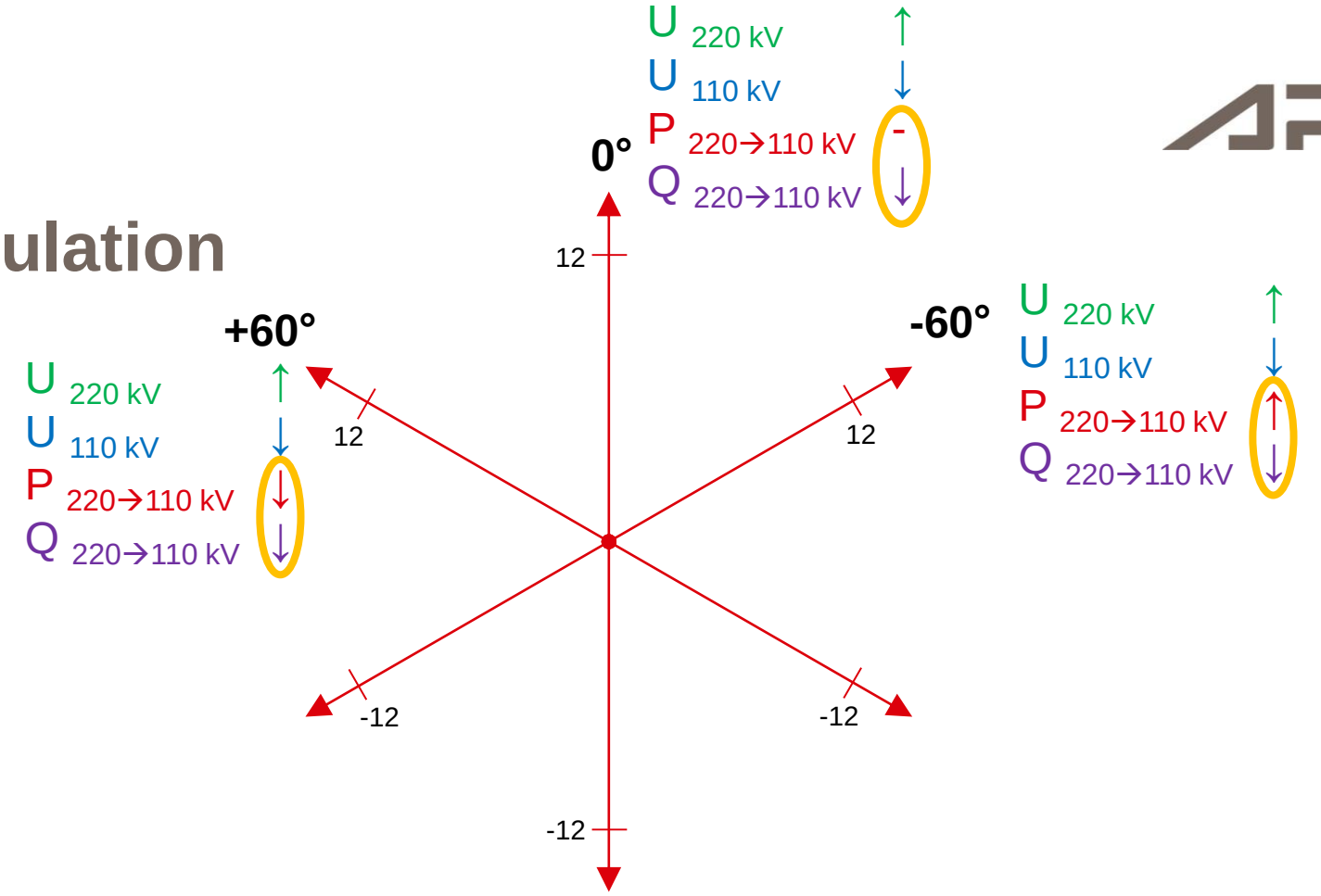
- **85 Transformers:**
  - 60°-Regulation: 80
  - **90°-Regulation (PST): 5**

Transmission grid of APG (2019)



0°- and 60°-regulation



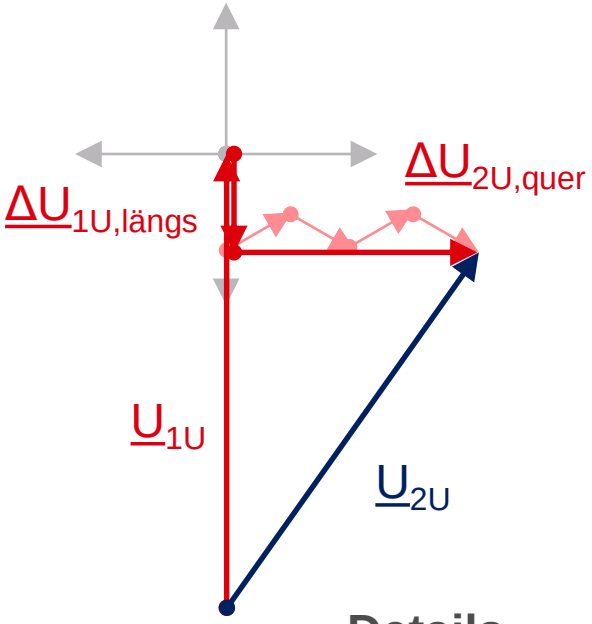


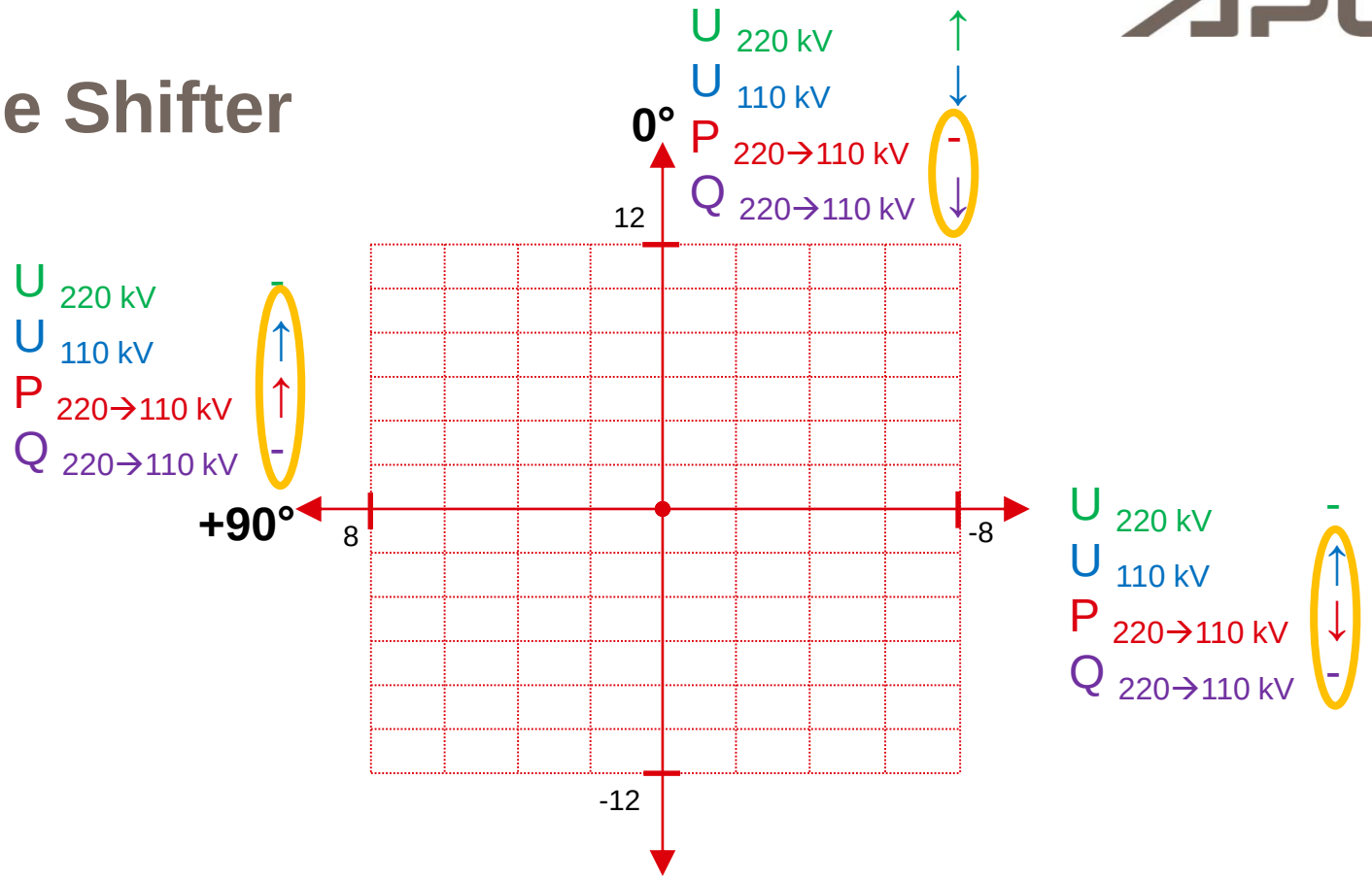
Details:

- Standardized: ± 12 steps (± 12 x 1,25 % = ± 15 % U_n)
- 0°-regulation: for U-regulation
- 60°-regulation: for common P/Q/U-regulation (limited)

Asymmetric Phase Shifter

90°-regulation



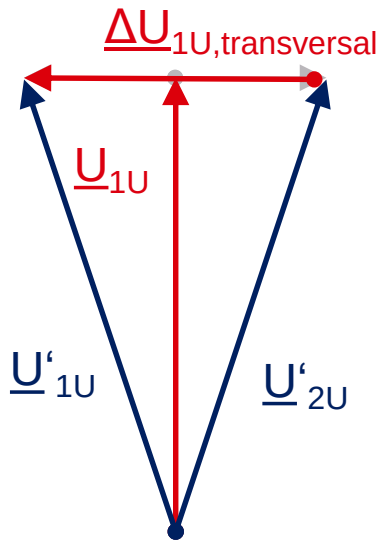


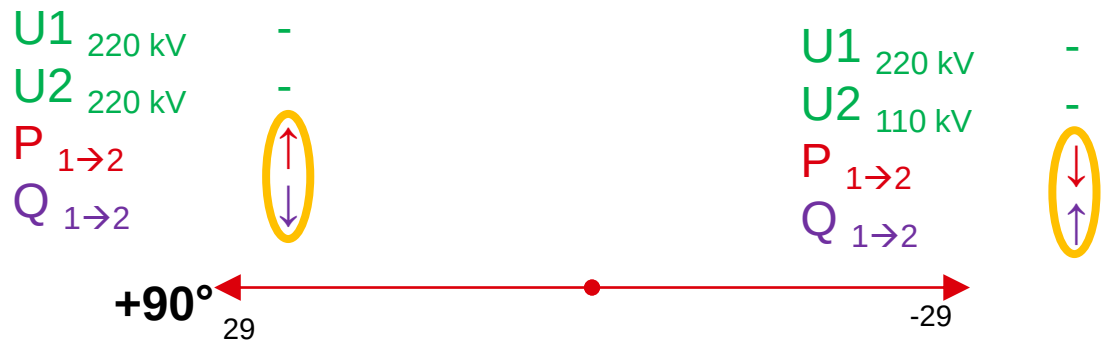
Details:

- Separated U- and P-regulation, not linear!
- appliaction:
  - Load flow control in spacious distribution grids
  - Voltage control due to change of load/generation close to substation

Symmetric phase shifter

90°-regulation





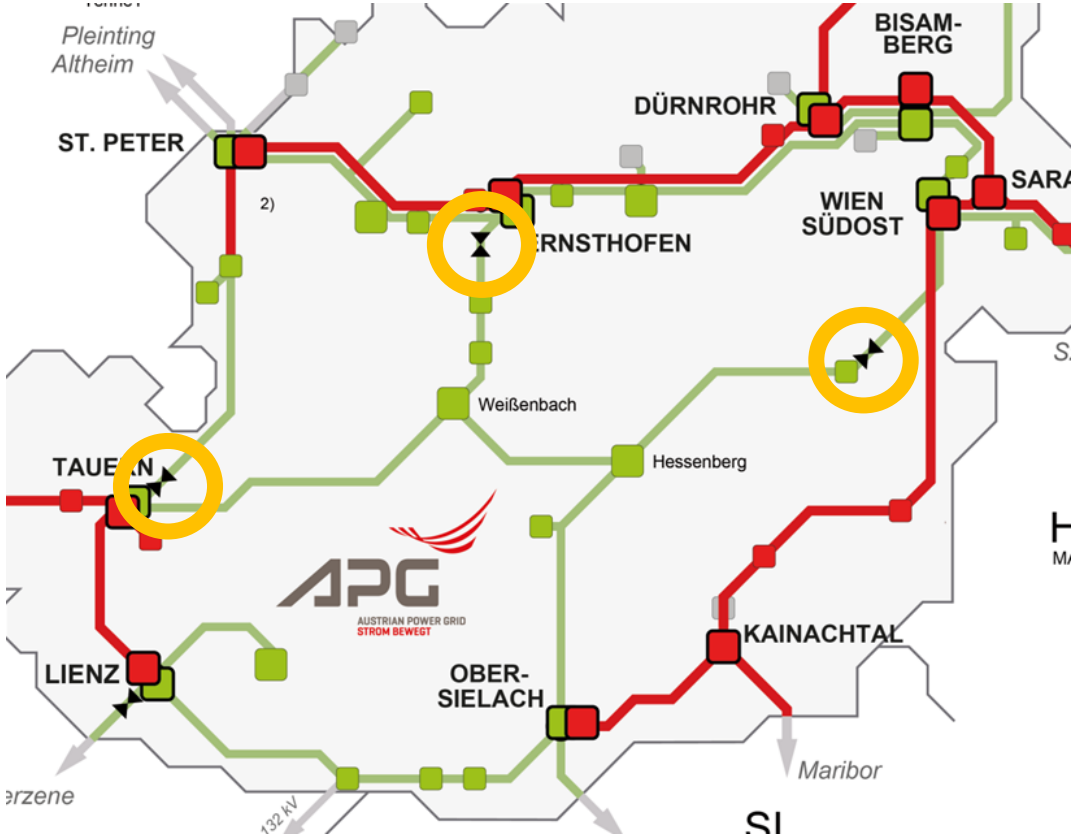
Details:

- constant transmission ratio
- Application: Limitation of P-flow on specific lines
- Individual design (rated power, no-load angle)

Symmetrical PSTs in APG‘s 220-kV-grid

- In operation since 2007
- Three identical PSTs

- **Application:**
  - Earlier: limitation of east-west-flows
  - Now: flow optimisation of specific lines

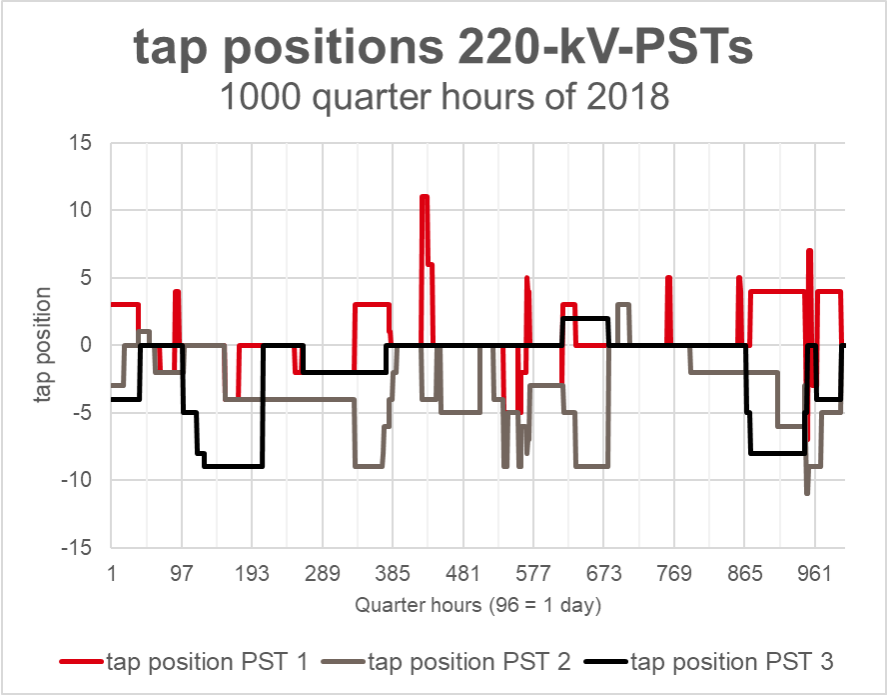


Technical Parameters

- Rated power: 600 MVA
- Rated voltage: 232/232 kV
- Max. no-load angle: ± 35°
- Series- and exciter transformer in separated tanks
  - Series transformer: 412 t
  - Exciter transformer: 440 t

<u>Operation experience:</u>

- Influence on active flow: ± 500 MW

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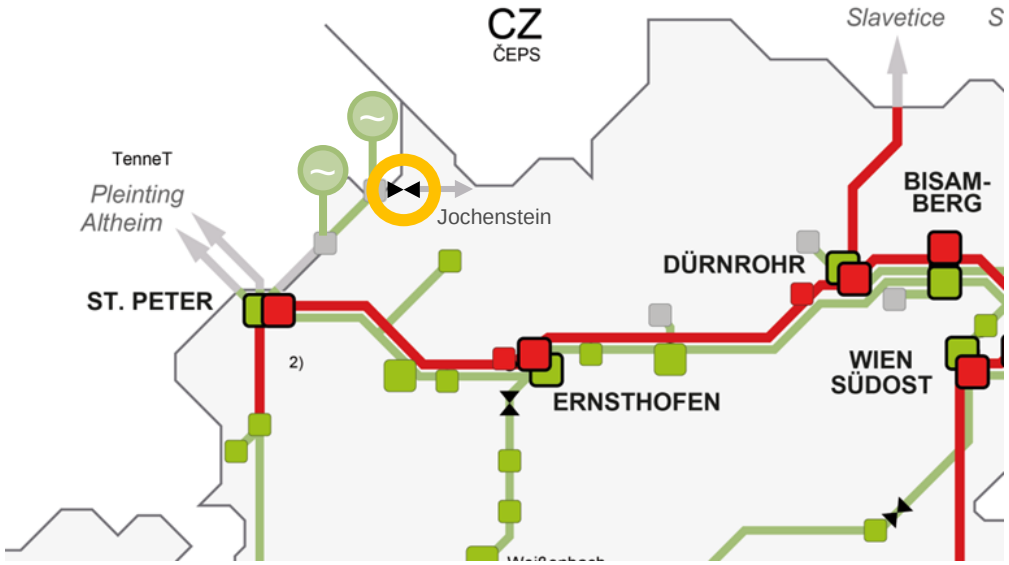
Asymmetrical PST in APG‘s 220-kV-grid

- In operation since 2018
- Separated U- and P-regulation

- **Application:**
  - Limitation of flow into 110-kV-grid
  - Voltage control due to infeed next to transformer



Technical Parameters

- Rated power: 200 MVA
- Rated voltage: 232/120 kV
- One tank transformer

<u>Operational experience:</u>

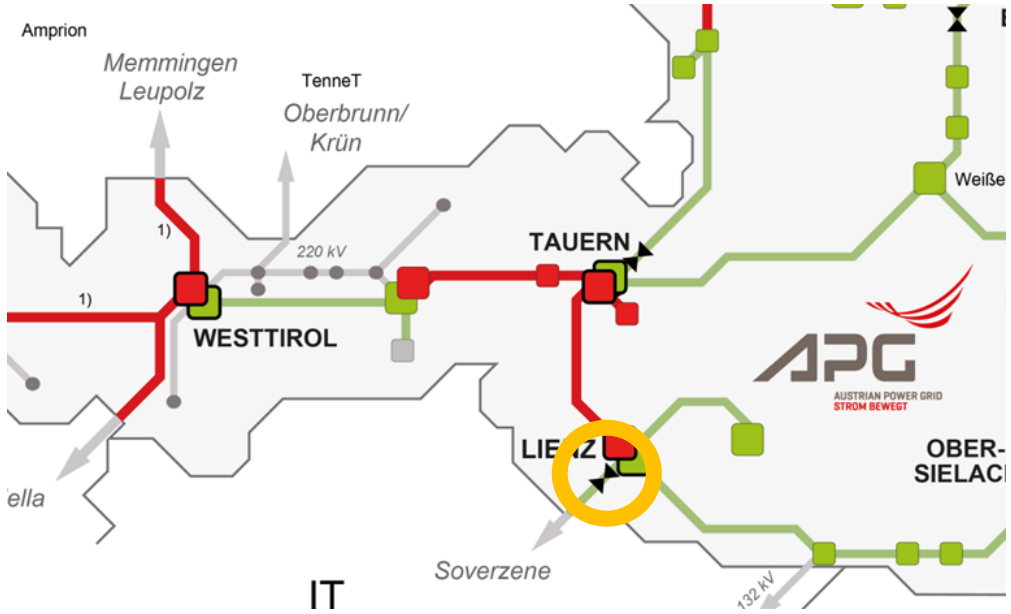
- Influence on active flow:

  ± 110 MW at end tap position ± 8

Symmetrical PST for cross border line Lienz (AT) – Soverzene (IT)

- In Operation since 2012

- **Application:**
  - Limitation of flow on cross border line to Italy

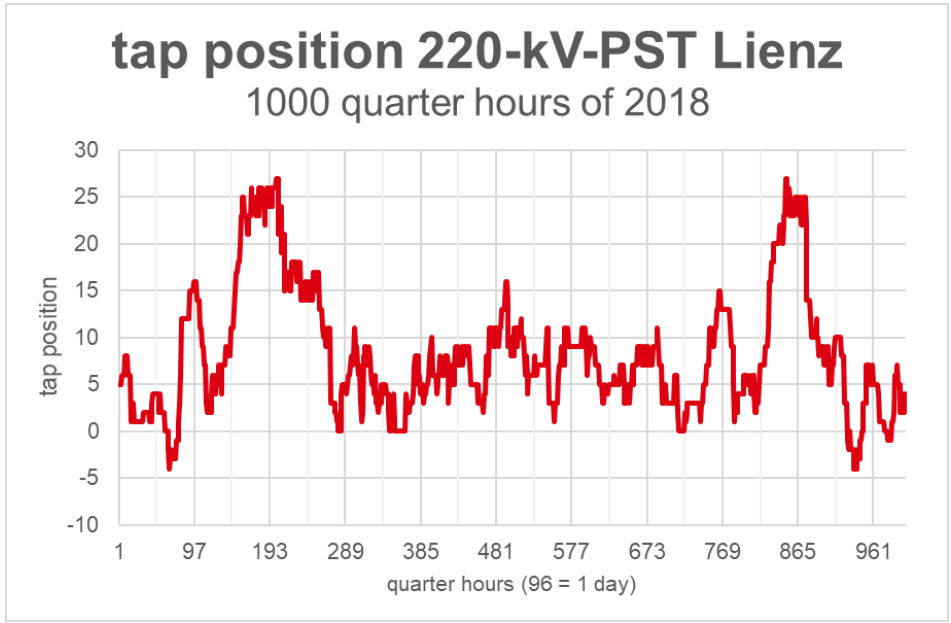


Technical Parameters

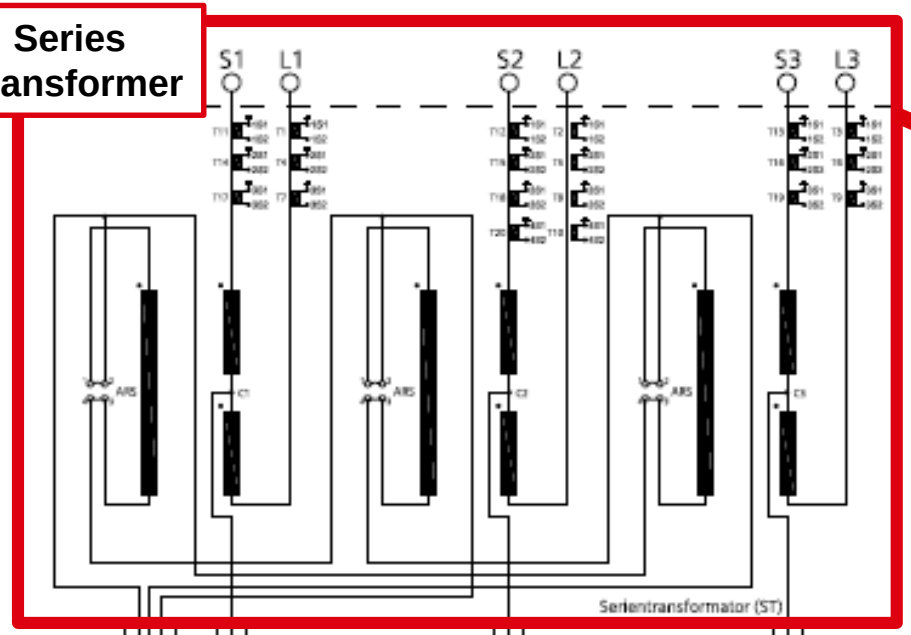
- Rated Power: 300 MVA
- Rated voltage: 232/232 kV
- Max. no-load angle: ± 60°
- Series- and exciter transformer in separated tanks
  - Series transformer: 381 t
  - Exciter transformer: 379 t

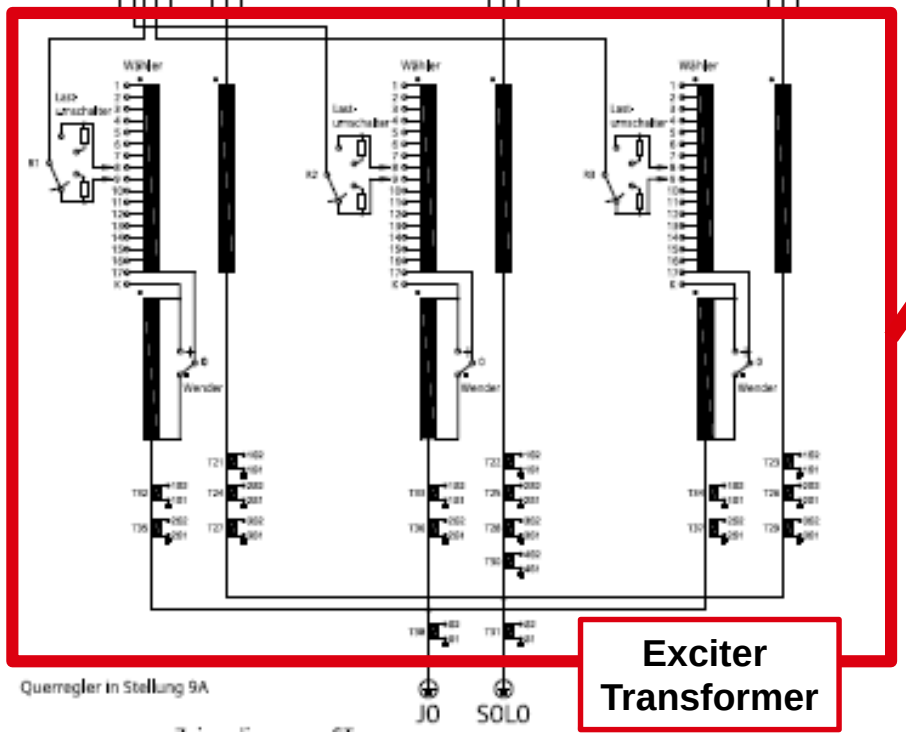
<u>Operational Experience:</u>

- Influence on P-flow: up to ± 500 MW
- Flow controller implemented

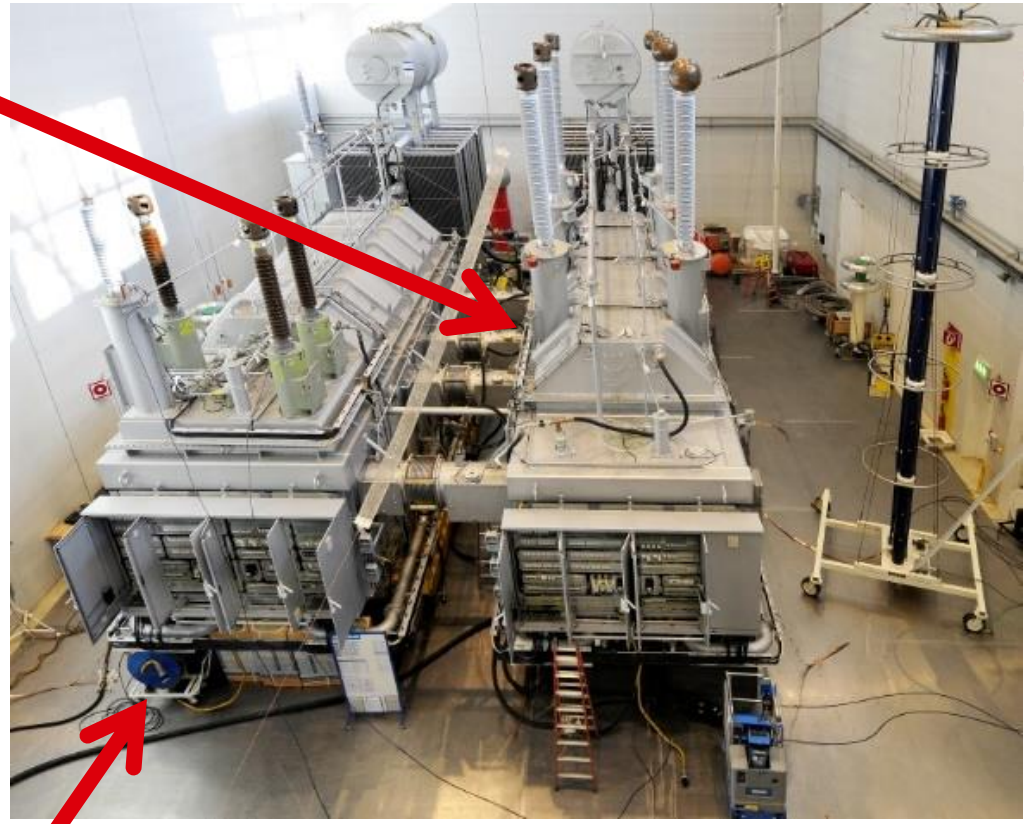


Series Transformer





Exciter Transformer

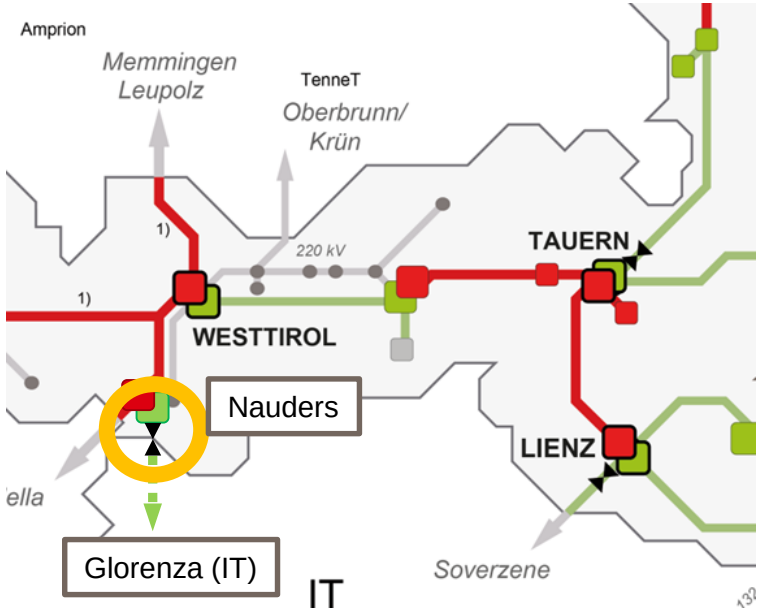


Symmetrical PST for cross border line Nauders (AT) – Glorenza (IT)

- Planned comissioning: 2023
- Tendering ongoing

Application:

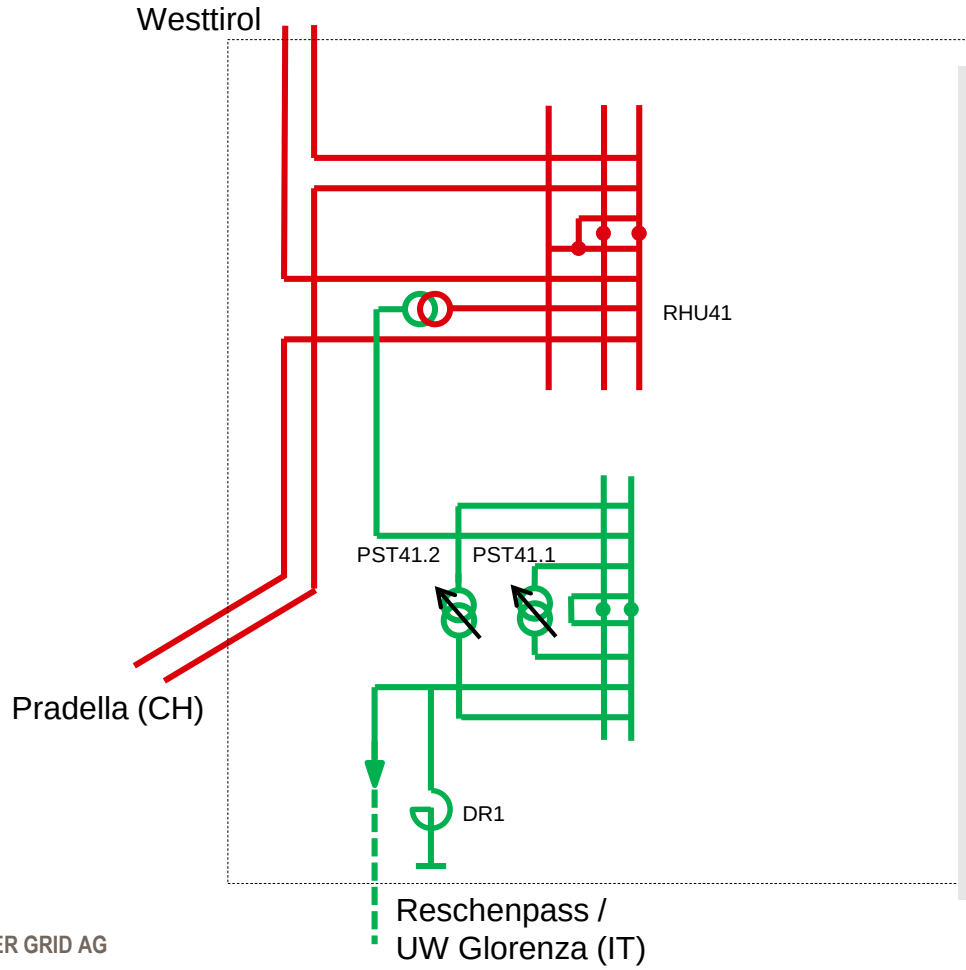
- 220-kV-PST for flow limitation on cross border line
- Variable coil for compensation of cable capacity



Specific details of projekt Nauders

- **Site located in alpine area**
  - 1.500 m above sea level (higher isolation distance)
  - Risk of icing
- **Site located next to highly frequented street**
  - Risk of salt fog
- **Transport limitation (for both train and street)**
  - Max. 155 ton
  - LxBxH 10,6 x 4 x 4,6 m
- **Earthing system**
  - High earth resistance due to stony underground

Specific details of projekt Nauders



400/230-kV-transformer
- 480/480/100 MVA
- four single phase units

2 x 230 kV PST
- Two identical PSTs in parallel operation
- Rated power: 225 MVA each
- ±40° no-load angle
- One tank design

Variable coil
- 230 kV oil connected to cable
- Regelbar 62,5 - 125 MVAr
  - Max. 10 MVAr per step

Many thanks for your attention!

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