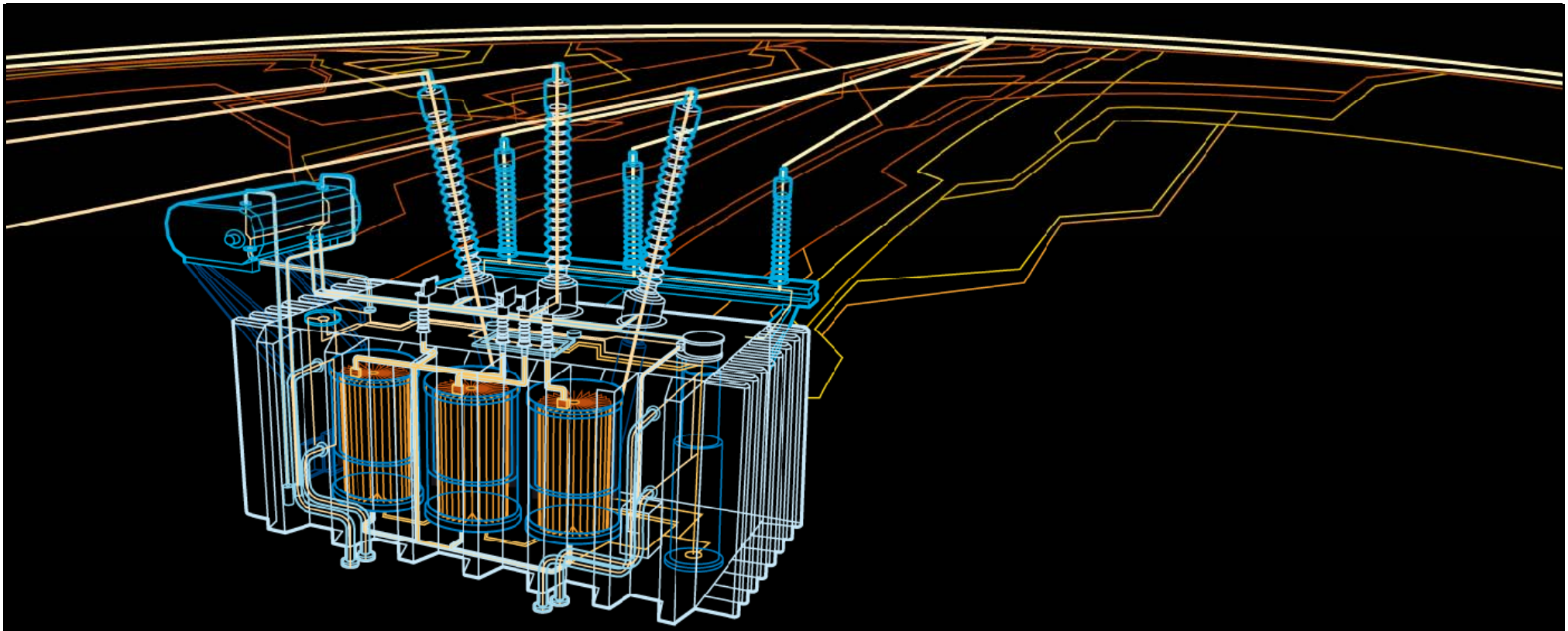


Thomas Schmidt, Global Product Manager Phase Shifters, Transformer Days 2011

Phase-shifting transformers

Optimized utilization of contracted transmission capacity

Benefits to you
Higher revenues, savings, increased reliability

How does a utility earn money?

- Generation of electrical power
- Transmission of electrical power
- Distribution of electrical power
- Trading of electrical power

Why phase-shifting transformers?
Components for efficient AC network operation

- Phase-shifting transformers (PST) enablers for the increased use of renewable energy
- PSTs optimize the utilization and/or losses of existing transmission lines
- PSTs belong to the portfolio of FACTS devices
- PSTs are the valve in your grid
- PSTs may manage n-1 situations

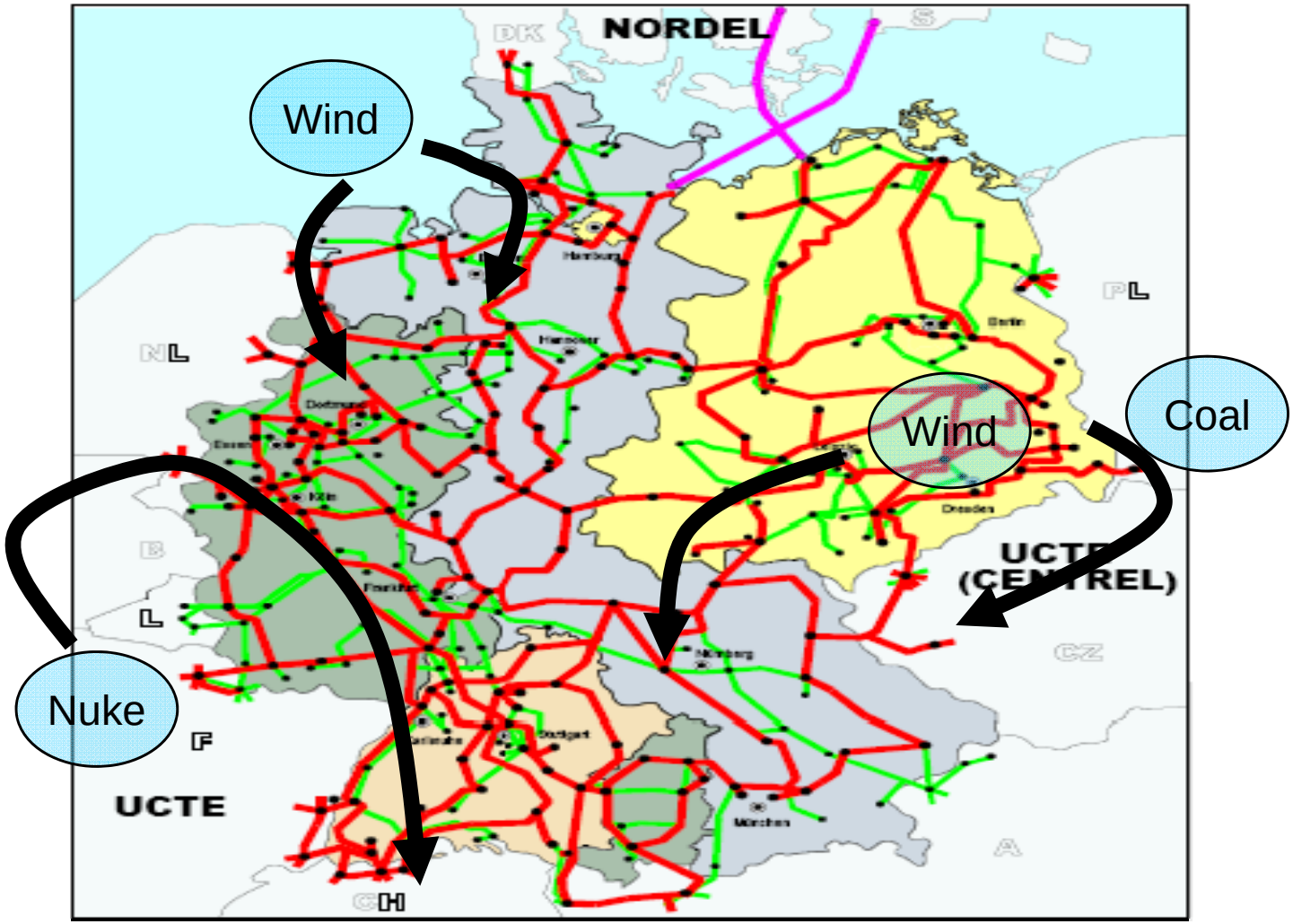
Why phase-shifting transformers?
Enabling the use of renewable power sources

- Transport of large amounts of electrical power over long distances will play an important role in achieving European goals for energy efficiency and for the use of renewables
- Bulk HVDC transmission will change power flow patterns in the supplied AC grids
- Increased injection of independent, often fluctuating renewable power
- Consequential AC transmission bottlenecks need to be managed ➡ PSTs!
- Permits for new transmission corridors are difficult to obtain

Examples for changes in load flow around Germany
Interconnections between countries

Congestion of North – South Corridor

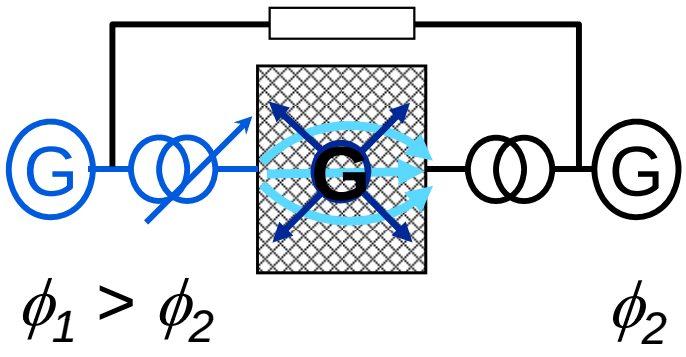
Changed load pattern due to nuclear power reduction



Unscheduled load of flows in Belgium

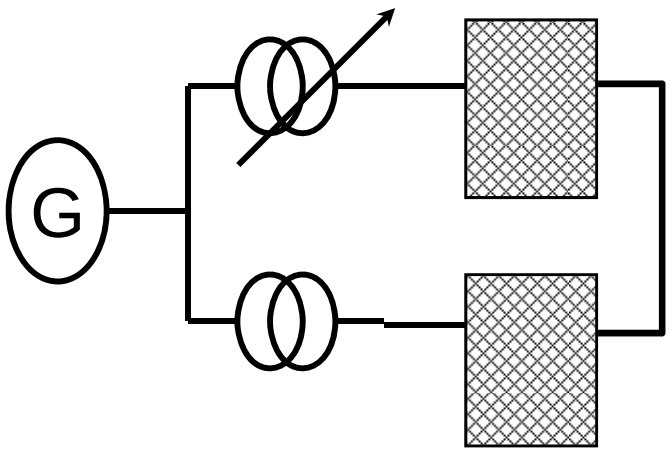
Congestion of East – West Corridor

Power flow control with phase-shifting transformers
Smaller scale applications



$\phi_1 > \phi_2$ ϕ_2

Cables dimensioned for radial flow



- Additional infeed into urban network - new generation pattern
- New power flows in EHV network cause angle difference at infeeds to municipal networks
- Need to block parasitic power flow and overload due to transmission angle differences in feeding network(s)
- Generator has contracts with two utilities
- Defined sharing of real power to different systems/customers

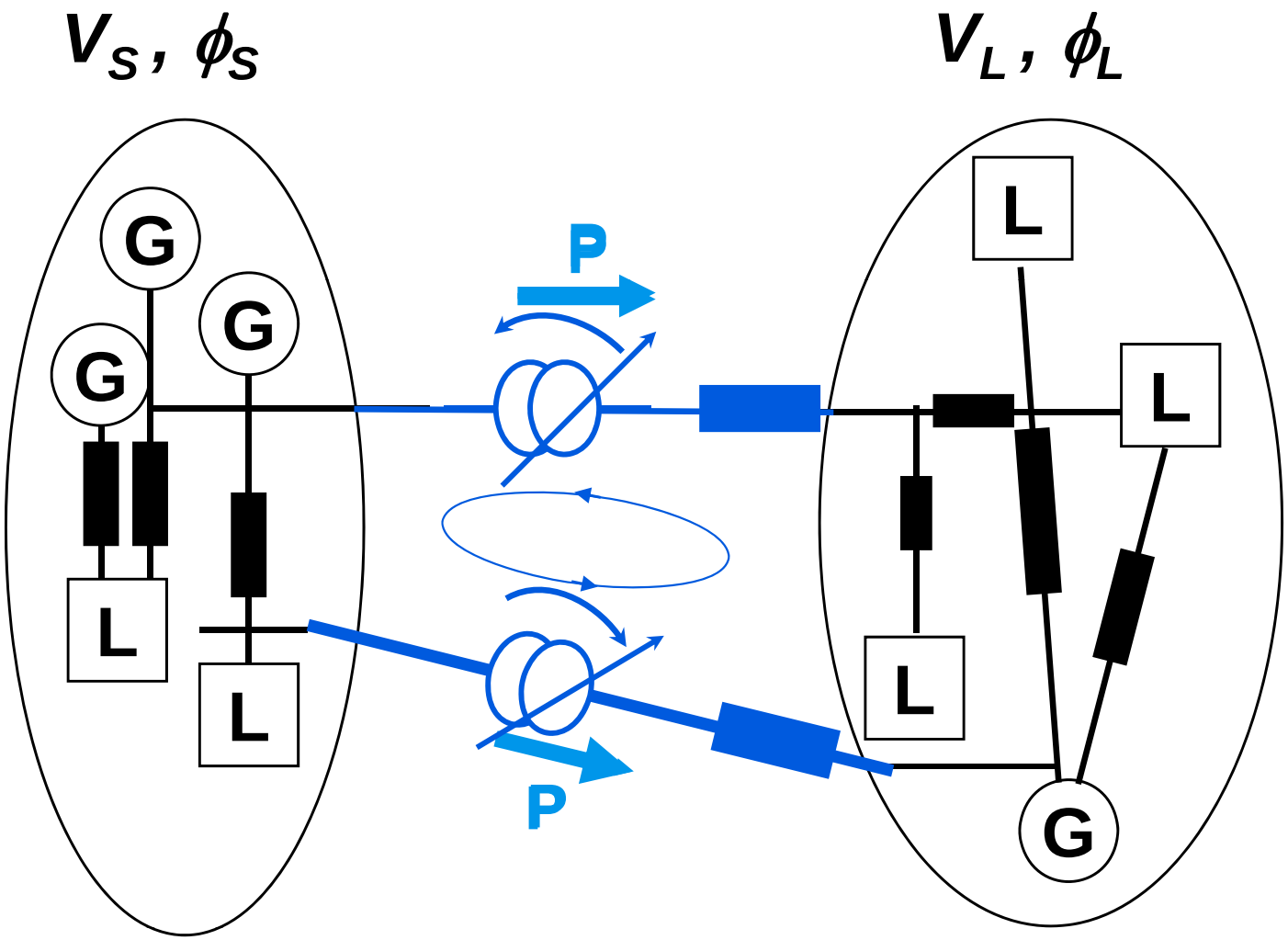
Power flow control with phase-shifting transformers
Optimization of load sharing and transmission capacity

Two synchronous systems.

Transmission lines with different impedances e.g. overhead / cable or 400 kV / 110 kV.

Transmission angle difference ϕ_S - ϕ_L drives power flow with unbalanced load sharing of lines.
The low impedance line is overloaded, limiting the total transmission capacity of the corridor.

PST impose an additional circulating current, thus improving the balance of power flows.
The total transmission capacity increases.

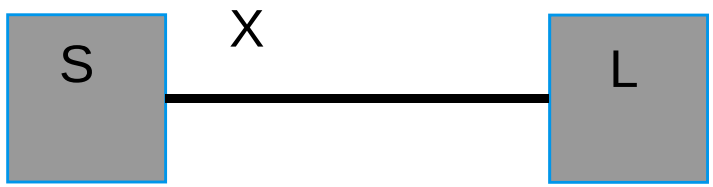


Typical applications for PSTs

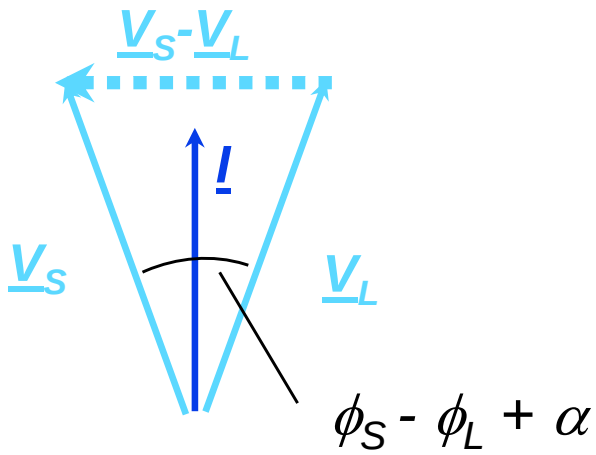
- Avoid transmission line overloading in normal operation
- Avoid post-contingency transmission line overloads
- Increase N-1 secure capacity of transmission corridors
- Control unscheduled load flows
- Keep load flows on contract paths
- Minimize overall losses in the network

Power flow control with phase-shifting transformers

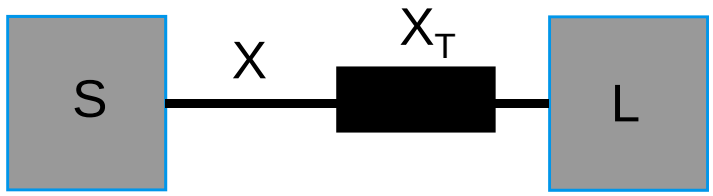
Phase shifting transformers are power flow controllers



$$P = \frac{V_S V_L}{X} \sin(\phi_S - \phi_L)$$

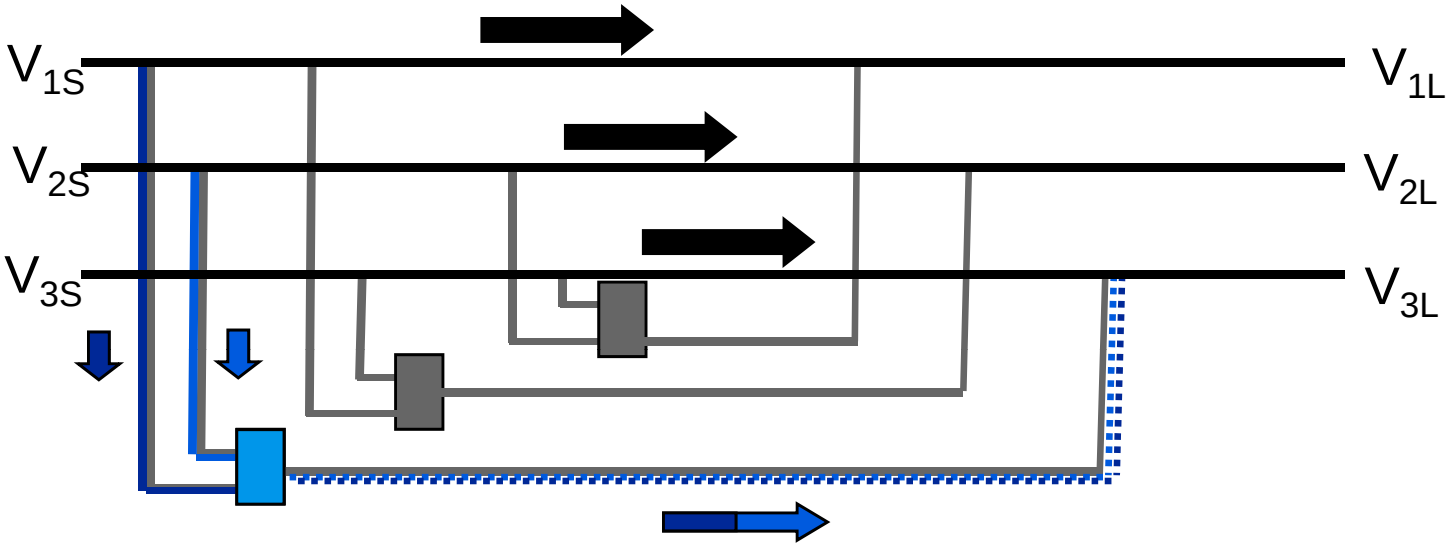


- The phase angle (equivalent to quadrature voltage) between two systems determines the power exchange



$$P = \frac{V_S V_L}{X + X_T} \sin(\phi_S - \phi_L + \alpha)$$

Technology
PST Principle



Starting with a symmetrical three-phase system with a certain load flow

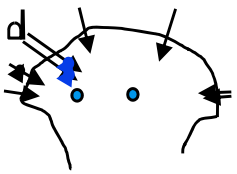
A PST shall be used to control the load flow

The PST takes a fraction of the two neighbor phases voltage

Combines them as a difference voltage

Which is then injected into the third phase

Example: TERNA Rondissone
Increase N-1 secure transmission capacity



Customer need

- Increase N-1 secure import capacity to Italy

ABB response

- Support by preliminary PST designs for system study and specification
- Support for protection and control engineering
- Supply of 2 x 1630 MVA PSTs, protection and control for PST and bypass bays, integration of > 50 heritage bays into MMI

Customer benefits

- Import capacity increased by approx. 1000 MW

Example: 1630 MVA, 400 kV / 400 kV, +18°C

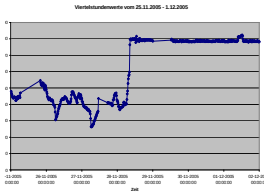
Example: Municipality of Ulm, Germany
Force power flow onto contract path

Customer need

- Maximize power supply via infeed with low transmission fee, but limit to 80 ± 0.5 MW
- Suppress transfer flows through the city's cable network

ABB response

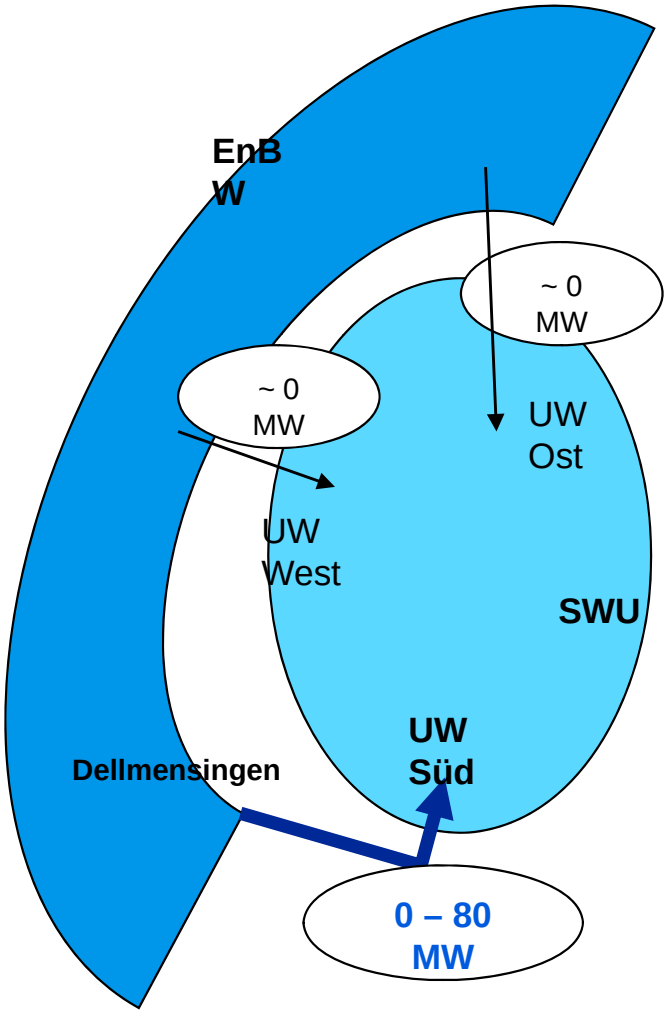
- Support with realistic PST data for system studies
- Help with specification of PST and control system
- Delivery of 100 MVA, 7° PST with very fine steps



Customer benefits

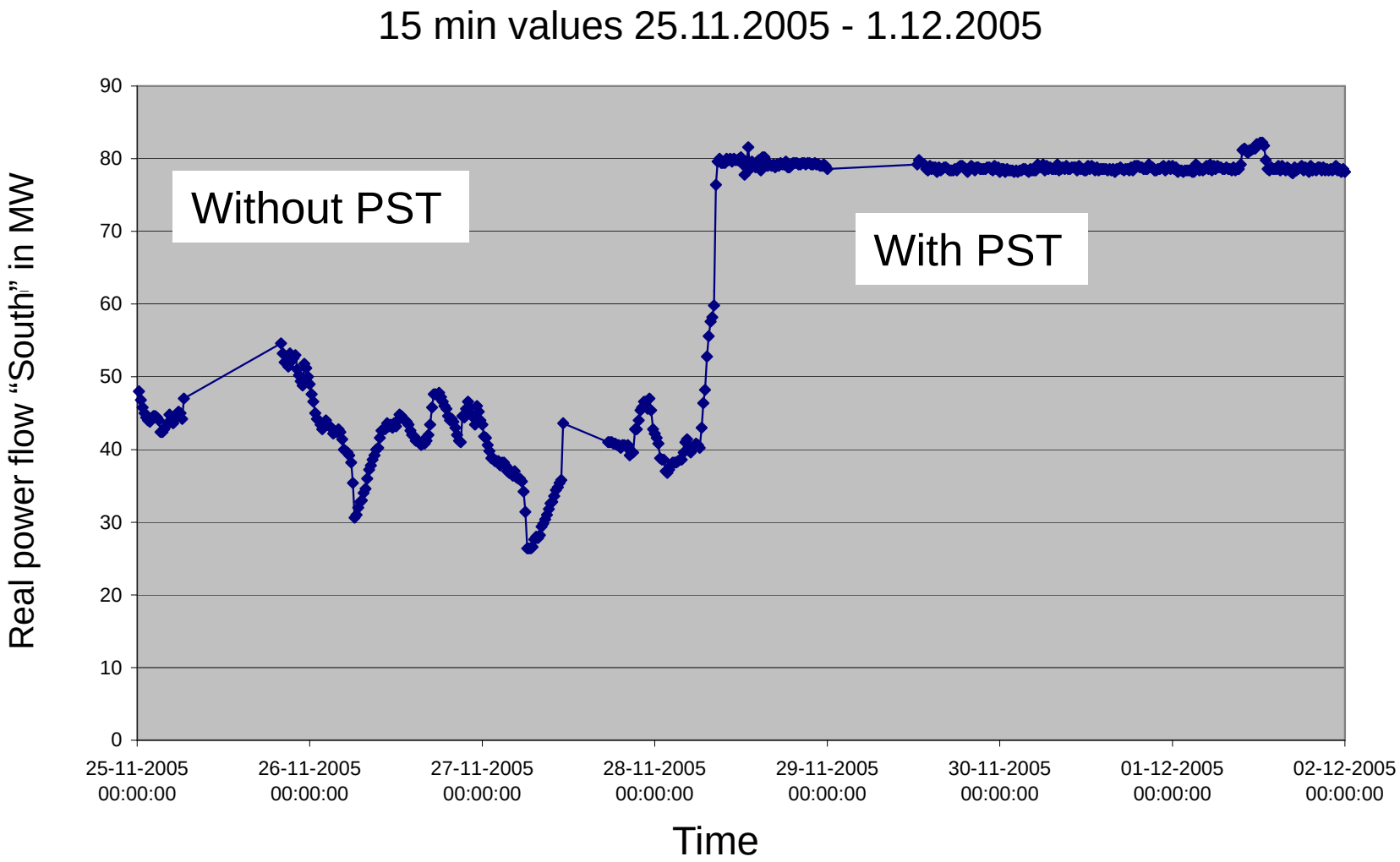
- Transmission fees to EHV grid operator absolutely minimized
- Pay-back in 18 months!

References
Economically driven PST project



- Municipal utility of Ulm, DE
- Supply from EnBW via three 110 kV substations
- One line leased with very favourable conditions up to 80 MW
- Incentive for PST: savings in transmission fees

Example: Municipality of Ulm
Pay-back in < 2 years, full exploitation of contract path

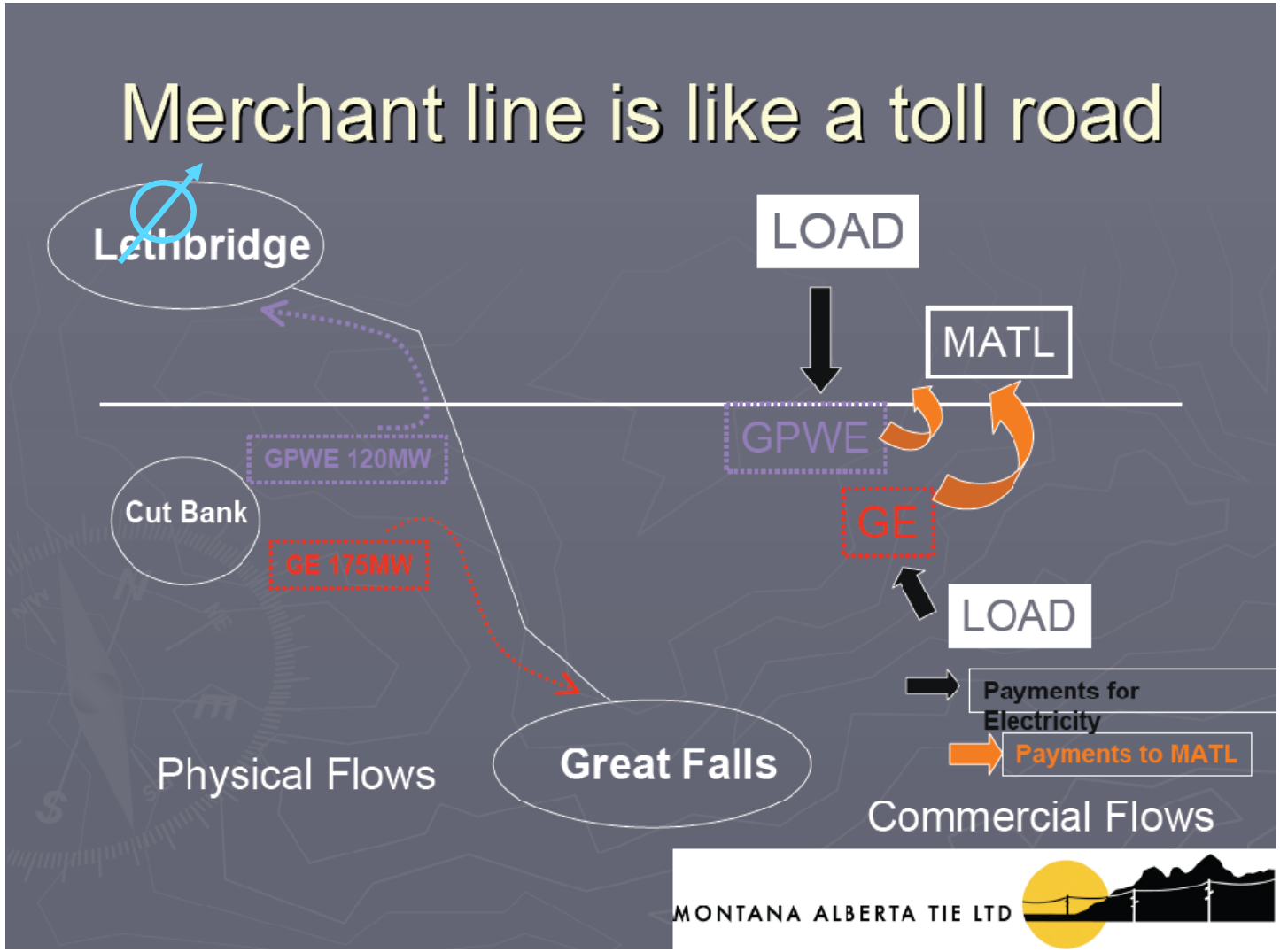


Example: Municipality of Ulm
100 MVA, 110 kV / 110 kV, +7° in 32 steps

Two active parts

Single tank

References – Power flow control on merchant line
MATL Lethbridge, Canada, 2005



Specifying a phase-shifting transformer

- Each unit is engineered to its specific purpose!
- Physical size and cost depends on throughput power and angle regulation range
- Angle regulation range to be specified by load flow studies
- Angle increments, short circuit impedance to be determined from system requirements
- Protection and control of PSTs has special requirements

It is highly recommended to contact your PST supplier early during the system specification stage!

ABB phase-shifting transformer solutions

- Center of Competence for PSTs in Bad Honnef since 2000
- Wide range of experience:
  - 100 MVA …1630 MVA
  - 110 kV …400 kV
  - + 7°…. ± 79°
  - Single and multiple active part designs
  - 87 units total, 24 delivered + 7 in pipeline from Bad Honnef, 2 in pipeline in Cordoba.
- Additional support can be offered for:
  - System studies (load flow, short circuit, insulation coordination)
  - Preparation of specifications
  - Protection and control

ABB's extra services for you
Support

Support during pre-tender stage

- Developing and optimizing economical transformer concept
- Quick iterations of technical solutions for system planners
- Special PST design tool
- Quick budgetary costing

ABB's extra services for you
Project execution and system studies

Professional project execution

- Project management
- Engineering
- Manufacturing
- Testing
- Transport
- Erection/ commissioning
- After sales service

ABB's extra services for you
Project execution and system studies

System studies

- Load flow
- Insulation coordination
- Switching
- Transformer protection
- Transient overvoltage protection
- Short circuit withstand capability
- Energizing the line with the PST

ABB's extra services for you
ABB activities

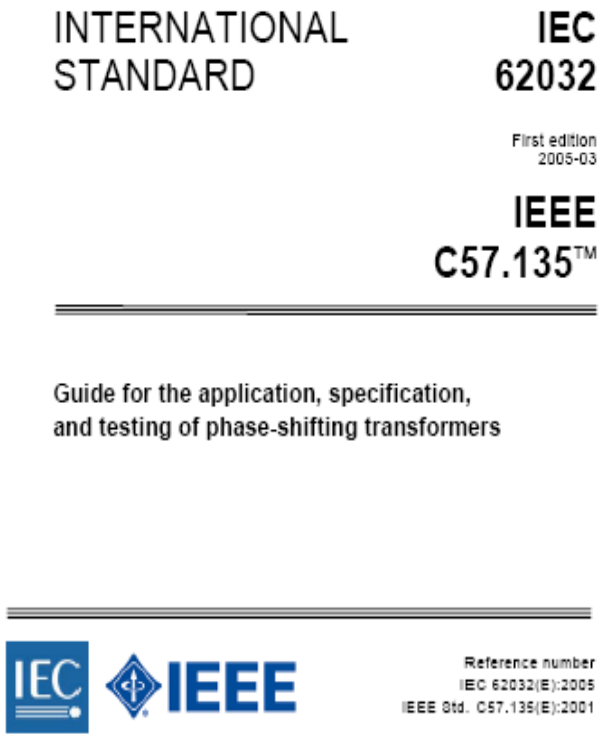
- Conferences
- IEC/ IEEE standardization
- Consultancy

- New solution development
- Research & Development

- Application support
- Trouble shouting

- Protection & Control
- Wide Area Monitoring (WAM)

ABB's extra services for you
Supporting material


INTERNATIONAL STANDARD

IEC 62032

First edition 2005-03

IEEE C57.135™

Guide for the application, specification, and testing of phase-shifting transformers

IEC IEEE

Reference number
IEC 62032(E):2005
IEEE Std. C57.135(E):2001

- IEC 62032 / IEEE C12.135 double logo standard
- Guide for the application, specification and testing of PSTs
- Extensive technical presentation
- PST flyer
- PST reference list
- PST checklist
- PST fast tender tool (ABB internal use only)
- PST bibliography

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