Coordination of phase shifting transformers using Wide Area Measurements

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Agenda

The need for Wide Area Monitoring, Protection & Control

Wide Area Technology

Existing references of Wide Area technology

Coordination of phase shifting transformers

Benefits and conclusions
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Benefits and conclusions
Today’s transmission systems...

...are more and more pushed towards their capacity limits

- Continuous gradual growth in consumption
- Environmental concerns restrict TS-extensions
- Increase in trading activities (cross border or inter-regional)
- Significant variation of power flow patterns
- Higher asset utilisation to increase profitability

**Consequence:** Increased occurrence of wide area disturbances
4 November 2006

51.00 Hz

50.00 Hz

49.00 Hz
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Benefits and conclusions
Window into the dynamic state of the power system by use of time synchronized measurements from dispersed sensors (Phasor Measurement Units, PMU)
Where does WAMS fit in?

**SCADA / EMS**
Monitoring at SCADA/EMS cycle rates actions initiated by long-term phenomena

**WAMS**
Coordinated measures based on dynamic view for monitoring, protection and control of power systems

**Object Protection**
Direct local actions by on-line status information

Dynamic  |  Reaction time  |  Static
User of Wide Area Monitoring Systems

Operation
- Enhanced operation security
- Increased awareness

Planning
- Increased system knowledge
- System parameter identification
WAMS applications

Monitoring and planning applications
- Increased transfer capacity corridor/bottlenecks monitoring
- Power/frequency oscillation monitoring
- Post-disturbance analysis
- Power system model validation

Control room applications
- Early warning of critical operating conditions
- Secure system operation at contingencies and secure restoration

Closed loop applications
- Capacity increase by optimized load flow:
  Parameter adaptation for
  SVC and Phase Shifting Transformers (PST)
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Benefits and conclusions
PSGuard / WAM-System Installations Worldwide

- Yellow circle: PSGuard WAM System in engineering phase
- Green circle: PSGuard WAM System delivered / in operation
PSGuard / WAM-System Installations Worldwide

PSGuard WAM System in engineering phase

PSGuard WAM System delivered / in operation

ETRANS
Switzerland
6 PMUs
Etrans Switzerland – responsible for HV grid coordination in Switzerland & South of Europe

Swiss grid within UCTE

220 kV
380 kV
Switzerland – also the PMU country

ETRANS monitors

- Phase Angles
- Line Temperature
- Power Oscillations
PSGuard / WAM-System Installations Worldwide

- EGAT Thailand
  - 4 PMUs

- PSGuard WAM System in engineering phase
- PSGuard WAM System delivered / in operation
PSGuard project at EGAT, Thailand: Power oscillation monitoring

Bang Saphan

Central-South power corridor

Surat Thani
PSGuard project at EGAT, Thailand: System design

System Monitoring Center (Master)

230 kV line, Measurement
Communication-link

PMU 1
1 x 3 U
2 x 3 I

PMU 2
1 x 3 U
2 x 3 I

PMU 3
1 x 3 U
2 x 3 I

PMU 4
1 x 3 U
2 x 3 I

Legend
- 230 kV line, Measurement
- Communication-link
- Application (bold)

Basic Monitoring (BM) for all PMU measurements

Power Oscillation Monitoring (POM)

Surat Thani

Bang Saphan

Ethernet TCP/IP

Legend

+2% 0.8 Hz
0% 0.8 Hz
-2% 0.8 Hz
PSGuard / WAM-System Installations Worldwide

- Austrian Power Grid (Verbund) 3 PMUs

- PSGuard WAM System in engineering phase
- PSGuard WAM System delivered / in operation
PSGuard / Wide Area Monitoring at Austrian Power Grid

Emergency line tripping at the rated break points to avoid blackout of APG’s grid.

380 kV line trip on 23rd August 2003 caused massive overload on APG’s grid.
System Monitoring Center (Master)

System Monitoring Center (Client 1) (Optional)

System Monitoring Center (Client 2)

Ethernet TCP/IP

220 kV

Wien Südost

Ternitz Schiene 1

Ternitz Schiene 2

PMU 1
1 x 3U
2 x 3I

PMU 2a
2 x 3U
3 x 3I

PM U 2b
1 x 3U
1 x 3I

Legend:
- 220 kV Leitung, Messung
- Kommunikationsverbindung

Basic monitoring (BM) für alle PMU Messungen
Phase angle monitoring (PAM) für alle PMU Messungen
PSGuard / Wide Area Monitoring at Austrian Power Grid - Phase 1 Installation

PSGuard
PSG850 Wide Area Monitoring
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Consequence of the electric utility industry deregulation and liberalization of electricity markets:

- The amount of power exchanges between regions raises caused by trading activities.

- Significant variation of power flows.
Observations

- Increasing number of phase shifting transformers in the European transmission grid
- Need to control and coordinate phase shifting transformers
- Availability of Wide Area Monitoring and Control Systems
Phase shifting transformer (PST) create a phase shift between its primary (source) and secondary (load) terminals.

Purpose of this phase shift is the control of the power flow in a complex network.

PST can control power flow to ensure flow patterns determined by market conditions or thermal constraints.

PST are typically controlled using local controllers.
A phase-shifting transformer (quadrature booster), is a specialized form of transformer
About phase shifting transformers

Quadrature booster on centre tap

100 MW generator

Substation 'A'

1:19
Tap 10
Phase angle 0°

50 MW

Substation 'B'

100 MW load
About phase shifting transformers

Quadrature booster on centre tap

100 MW generator

Substation 'A'

1:19
Tap 10
Phase angle 0°

50 MW

Substation 'B'

100 MW load

Quadrature booster on 'buck' tap

100 MW generator

Substation 'A'

1:19
Tap 4
Phase angle -7.5°

50 MW

Substation 'B'

100 MW load

73 MW

27 MW

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Control of Phase Shifting Transformers (PST)

- Continuous logging of system quantities for existing SCADA and off-line analysis
- Improved State Estimation possibilities
- On-line monitoring of power system reaction during manual PST control
- Optimal automatic control of PST as a group
Austrian grid

PSGuard
PSG850 Wide Area Monitoring

3 PST ordered and in installation
Step 2 Simulation: PST with local control and fault on corridor

Local PST control

Local PST control
Step 2 Simulation: PST with local control and fault on corridor

Local PST control

Local PST control

Local PST control
Step 2 Simulation: PST with local control and fault on corridor

- When the fault occurs no corridor is overloaded
- During the fault time the power is not equally redistributed between corridors
- Margin available to transfer more power also when a fault occurs
Local control of phase shifting transformers is not optimal

**Targets of Wide Area Control**

- **Priority 1:**
  Avoid overload on the three corridors

- **Priority 2**
  Equally redistribute power flow also when a fault occurs

- **Priority 3**
  Try to push more power through the corridor without violating the overload limit
Step 4 Simulations: 3 PST and Wide Area Control, fault on corridor

Load increase in all corridors

Coordinated Wide Area PST control
Step 4 Simulations: 3 PST and Wide Area Control, fault on corridor

Coordinated Wide Area PST control
More transmission capacity

All three corridors are operated much closer to their limits

When the fault occurs in one corridor the power flow is equally redistributed

The other two corridors „help“ the faulted one; the total amount of power transferred is not decreased

Avoidance of harmful interactions of multiple PST devices (i.e. oscillations)

Fast and precise reaction of the system achieved by Wide Area close loop Control based on phasor measurements
Additional benefits

- Minimization of losses in the transmission grid, if phase shifting transformer used for power flow control in-between network levels

- Better usage of all existing assets

- Avoidance of critical situation by fast control actions at contingencies
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Conclusion and summary

- **Risk management and capacity improvement** by coordination of phase shifting transformers using Wide Area Measurements

- 3 Consecutive steps:
  - PMU & WAMS installation
  - Integration into network control
  - Closed loop control
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