Applying Voltage/VAr Management to Support Energy Markets - Practical Experience

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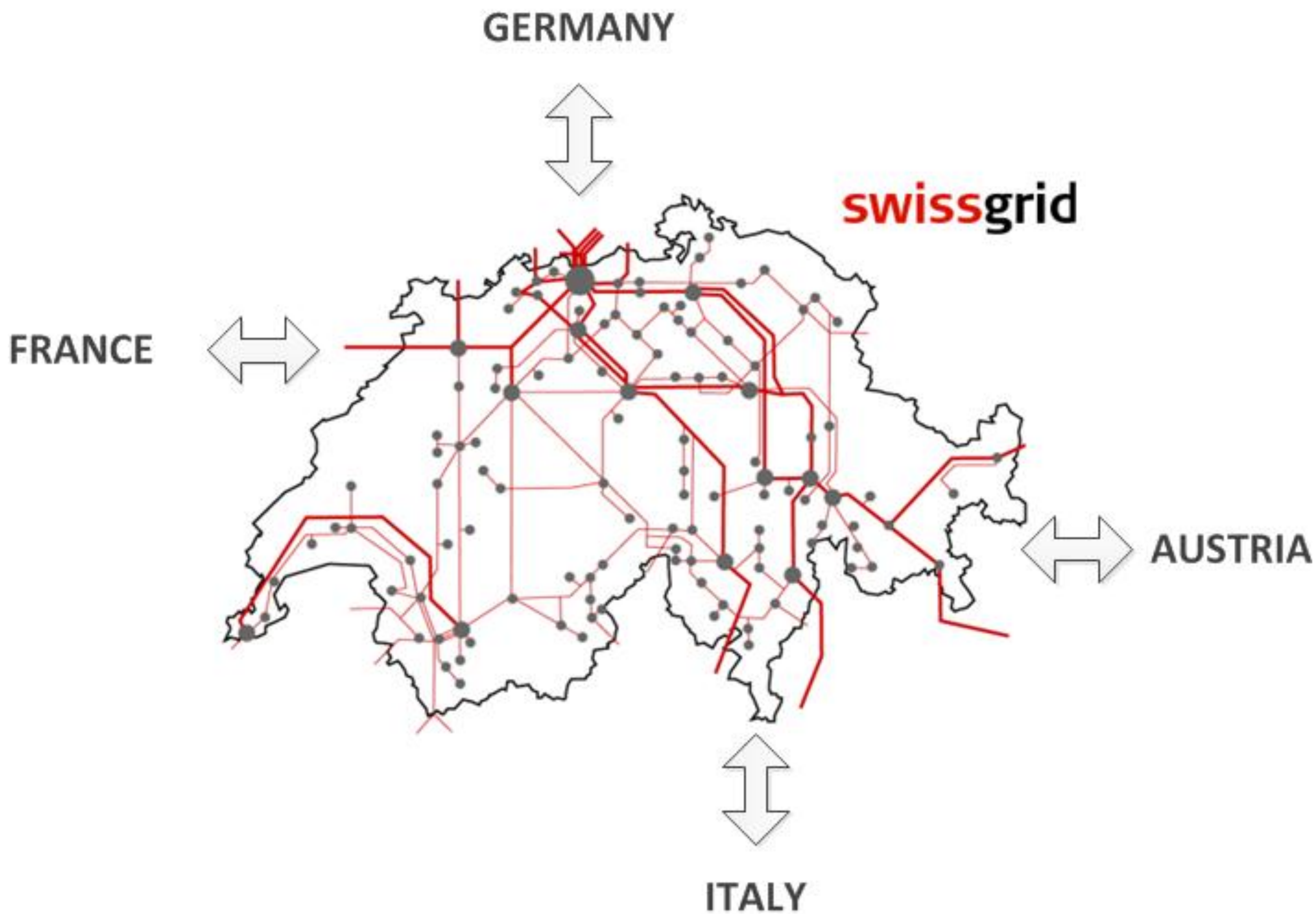
This Talk is About

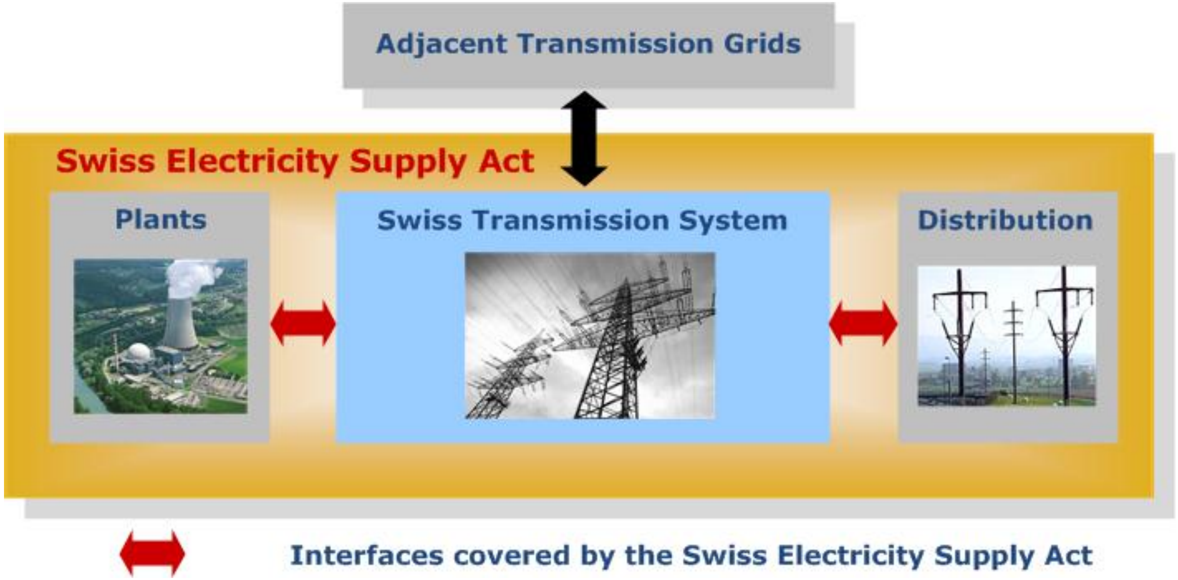
- Day Ahead Reactive Planning [DARP]
  - Via Optimal Power Flow (OPF)
- A specific implementation
  - In Swissgrid - the ISO/RTO of Switzerland
  - With potential similar applications elsewhere

Swissgrid – A European Energy Exchange Hub

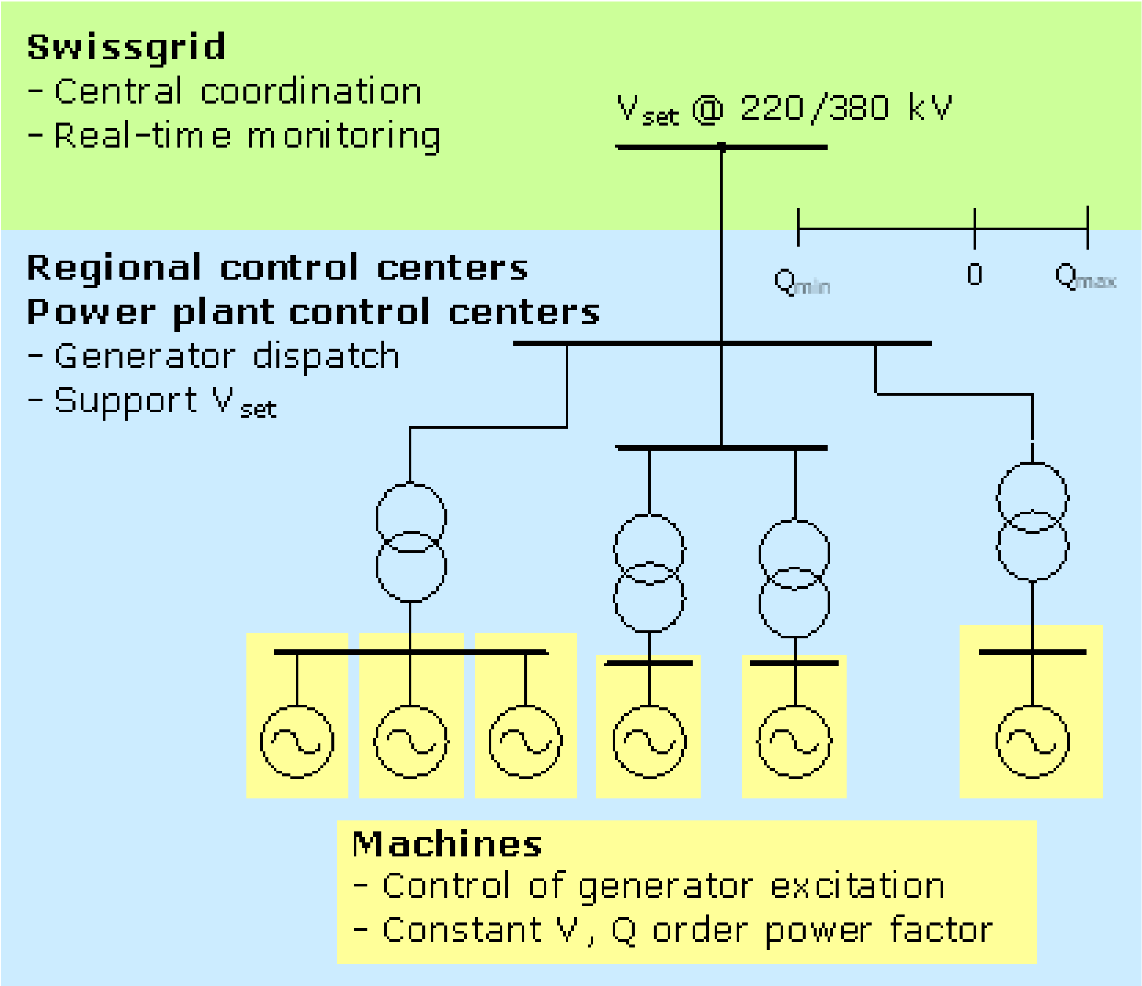


Swissgrid Voltage Control is a Major Operational Issue

- To cater for the many changing patterns of power flows across the Swiss transmission network
  - Coordinating all the reactive resources available
- Maintaining operational reliability
  - Implying operational flexibility



Swissgrid Central Voltage Coordination

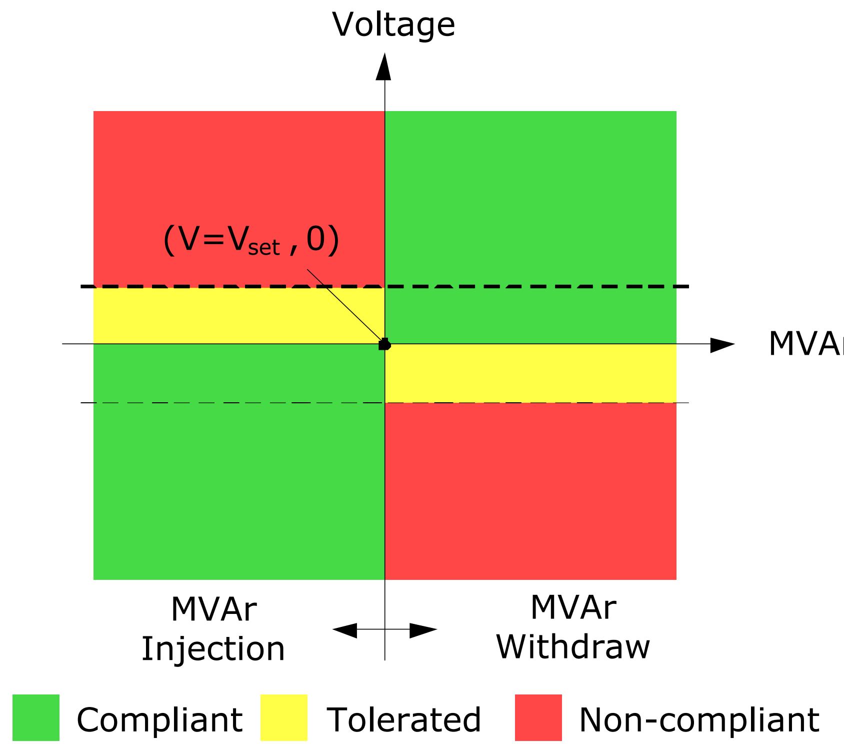


Voltage Control Requirements

- Keeping voltages within operational limits at all nodes, at all times
- Compliance with Entso-E CE Operation Handbook
  - Coordinate voltage control with neighboring grid operators
  - Sufficient reactive resources and reserves
- Minimize total cost for
  - Active power transmission losses
  - Reactive energy payments to generators
- ***These requirements are not mutually synergistic***

Voltage Control - Power Plant Participation

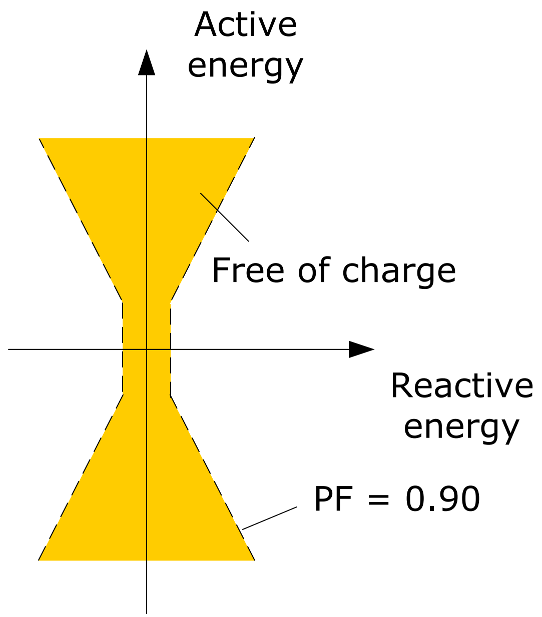
- Power plants at 220/380 kV are obliged to participate in voltage control
- Mandatory reactive power range
- Voltage set-point at 220/380 kV
- Generators have to pay a default MVArh penalty rate if they are in the red area



- Every MVArh supporting the voltage set-point is compensated by a default payment rate (CHF/MVArh)

Voltage Control - Distribution Grid Participation

- Limited ability to control voltage at 220/380 kV
- Incentive to limit reactive power exchanges with transmission grid



- Choice between active and passive participation at transmission system voltage control
  - **Active** participation: treated like a power plant
  - **Passive** participation: charge for excess reactive energy (CHF/MVArh)

DARP (Day-Ahead Reactive Planning)

- Determination of optimal voltage set-points
  - The OPF produces reactive schedules to support voltage security, without compromising MW security
- Optimization based on hourly forecast snapshots
  - Each reactive OPF solution is based on a scheduled MW dispatch from day-ahead SCUC, which is secure in terms of thermal (and some stability) constraints
  - An accurate AC model of the network is used
- Extension of Entso-E CE Day-Ahead Congestion Forecast (DACF)

The Hourly Reactive Scheduling Process

Data Preparation

- Merge hourly data
  - Network model, including MW schedule (from EMS)
  - Generator MVAr limits
  - Branch group definition

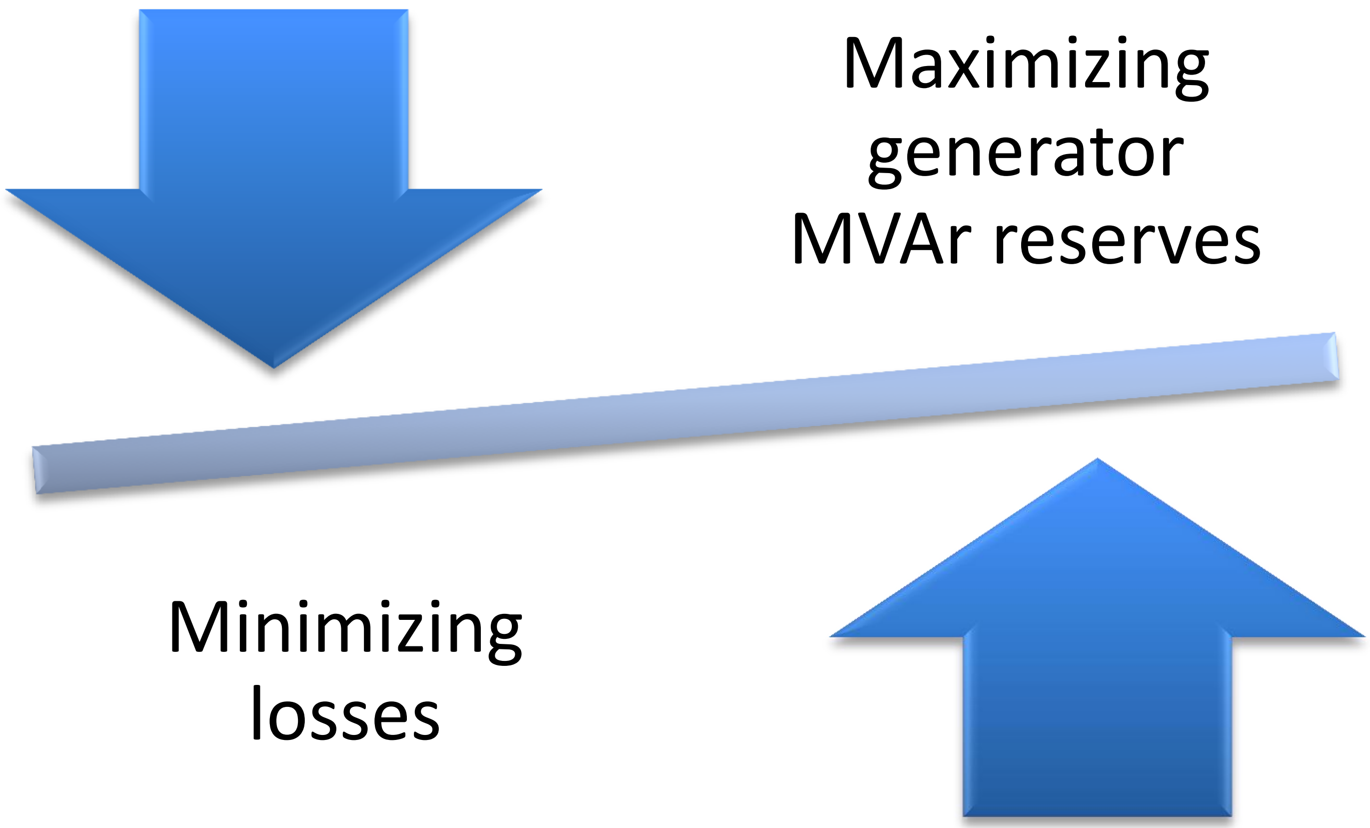
Reactive Optimization

- Perform reactive OPF, computing optimum
  - Settings for regulated voltages, taps and other devices
  - Switching for shunt reactive devices
  - Settings for phase-shifting devices

Output Results

- Voltage settings and profiles
- MVAr dispatches
- Taps (in-phase & out-of-phase) settings
- Grid losses

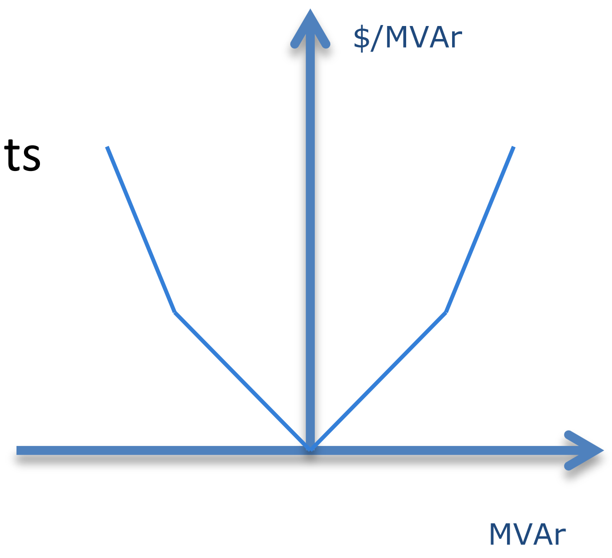
A Practical Objective – A Tunable Balance Between



The OPF Objective Function

Min: $\omega_1 \Sigma$ MW losses + $\omega_2 \Sigma$ MVAr losses + $\omega_3 \Sigma$ MVArs

- Losses are for designated or all branches and shunts
- Maximizing MVAr reserve ≅ minimizing MVAr generated
  - Therefore, minimize
    - MVArs supplied/absorbed by generating units
    - MVArs through network interfaces
    - By applying "cost curves" to MVArs, discouraging operation near limits



OPF Reactive Controls

- Regulated voltage set points
  - Regulated by generators, LTC taps or SVCs
- Directly dispatched transformer taps
- Shunt MVArs
- SVC MVAr set points
- Transformer phase angles
  - For loss and cost minimization objectives
- With multi-level priority activation/deactivation

OPF Reactive Constraints

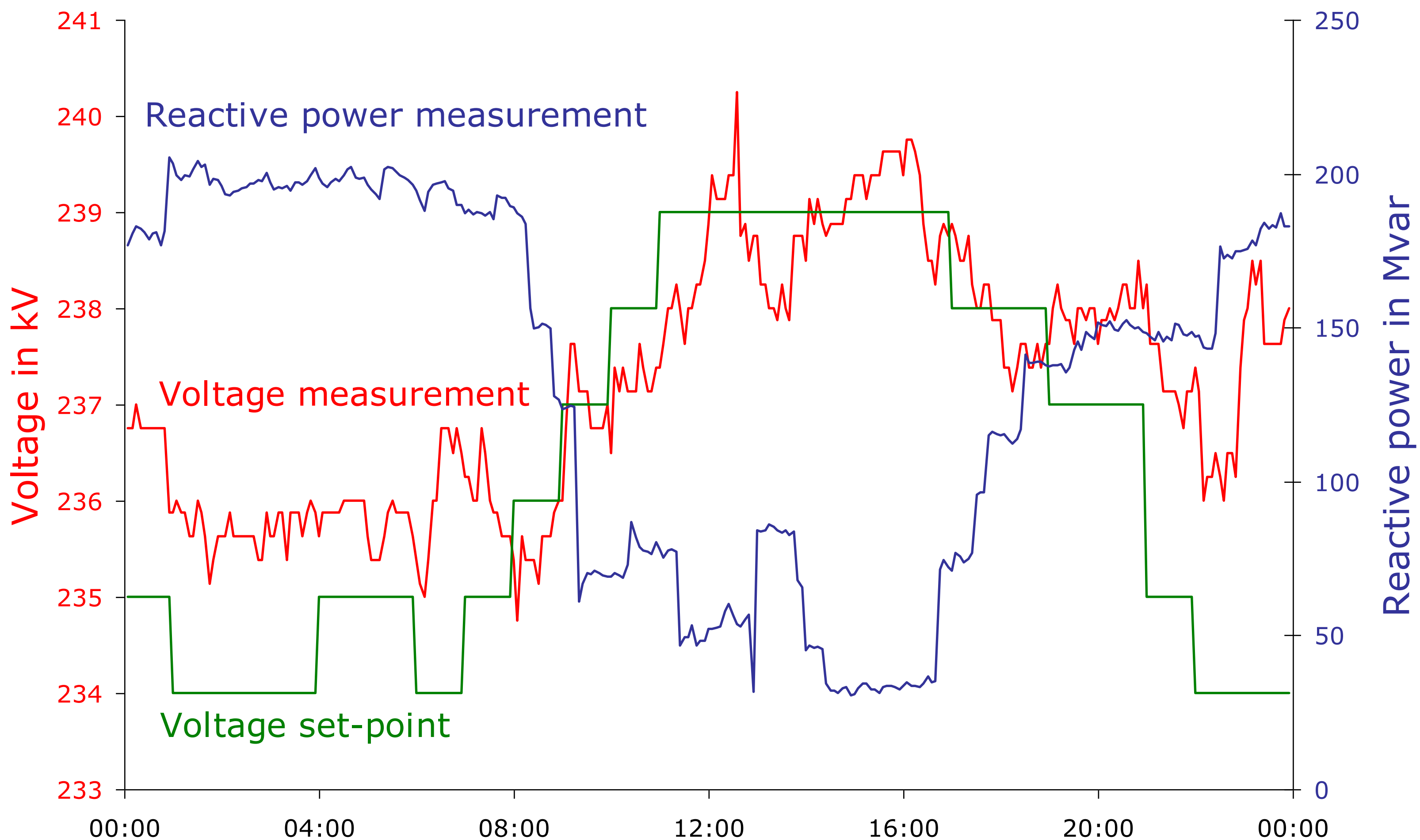
- Full set of constraints (pre- and optionally post-contingency)
  - Branch flows (rated in MVA or amperes)
  - MVAr branch group limits
  - MVAr interchange between zones
  - MVAr generation reserve
  - Generator MVAr limits
  - Voltage high-low limits & rise-drop limits
  - Voltage magnitude differences between assigned pairs of buses
  - Bus voltage post-contingency change
  - Timed response for slow control adjustments
  - Multi-level priority activation/deactivation

Not all of these constraints are currently used by Swissgrid

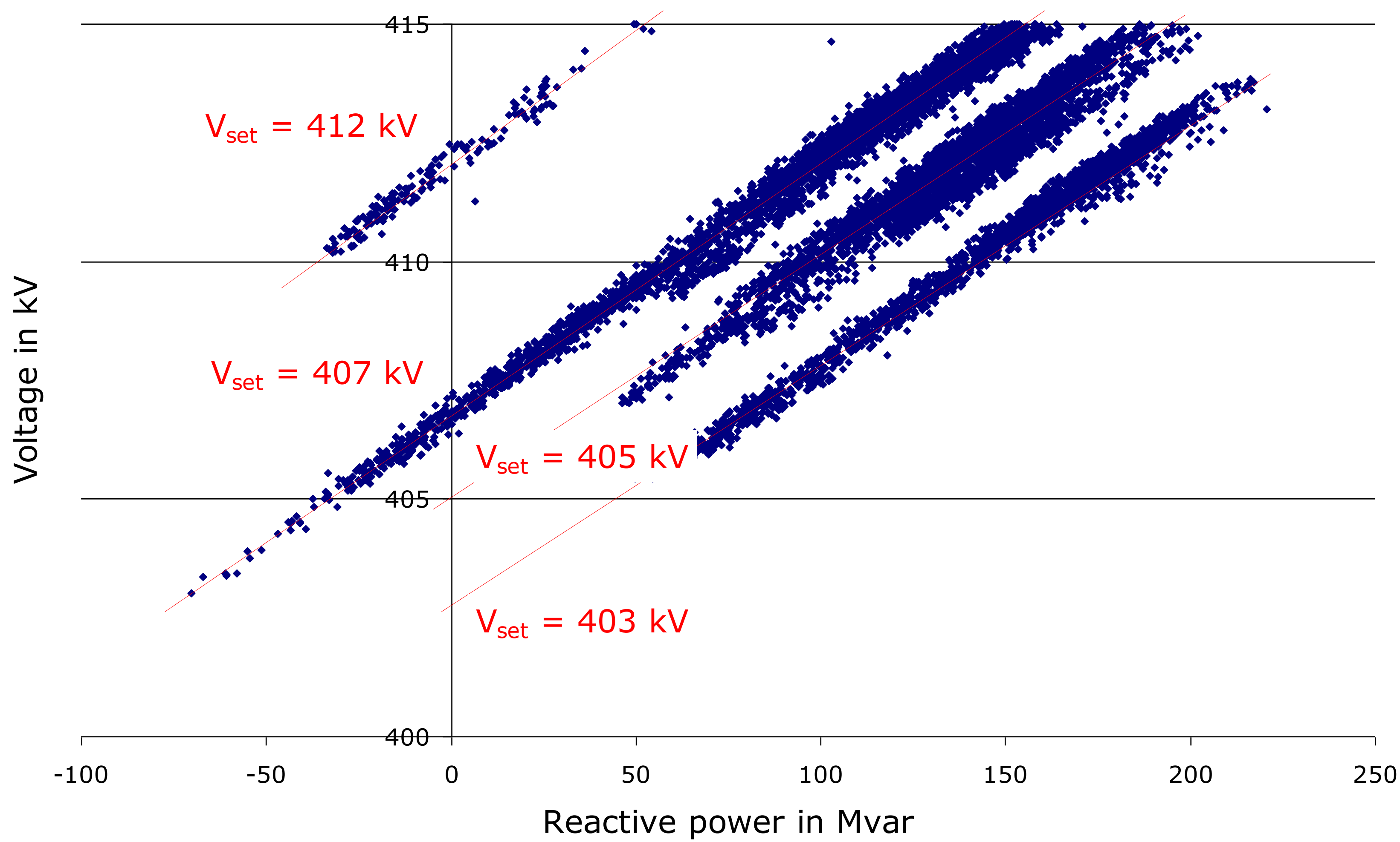
Swissgrid Implementation

- In use for 2 ½ years
- Runs every day in 24-hour look-ahead mode and updates when needed (e.g. following major events)
- Objective function weights are adjusted according active losses prices (hourly profile of average MWh price) and reactive power (standard payment to generators for each MVArh

Example of Swissgrid Daily Schedule



Power Plants: Typical kV x MVAr Pattern



Swissgrid Results & Experience

- Overall better voltage profile
- Reduction of reactive extra exchanges with distribution grids by 50%
- Limitation of unwanted reactive exchanges with neighboring grids
- Economic incentives to grid participants are an effective control instrument
- Economic benefits to Swissgrid are estimated as up to CHF 100k in a "good" operation day
  - Loss reduction
  - Reduced payments for generator MVAr

QUESTIONS ?