Dynamic Models for Hydro Power Plants

Parameter Identification based on Test Measurements

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1. Current Power System Operation Challenges
2. Dynamic Modelling Setup
3. Application Examples
4. Conclusions and Outlook

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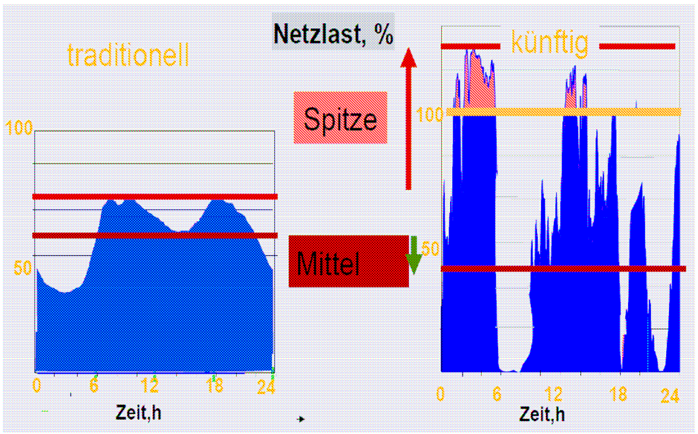
Current Power System Operation Challenges

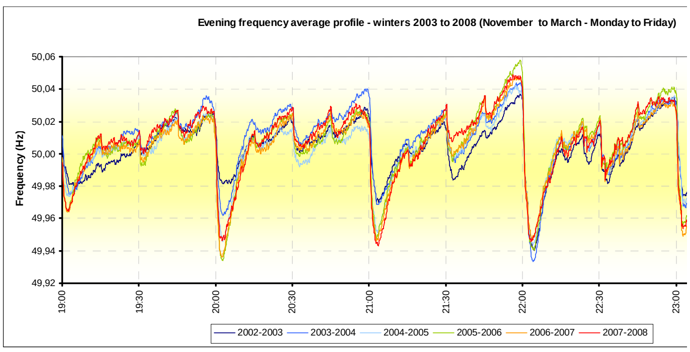
- Number of system actors is increasing:
  - Power System Operator (transmission system, distribution system)
  - Power Plant Operator
  - Ancillary Services Provider
  - Market Operator, Balance Responsible Parties, Traders
- Number of interfaces is increasing
- Volatility of power flows is increasing
- **Enhancement of system tools is required!**

Trend of Power Flow Changes



Source: B. Buchholz, CIGRE/CIRED Conference, 01.03.07 ETH Zürich

Worsening of Frequency Quality



Source: UCTE FQI Report Aug. 2008

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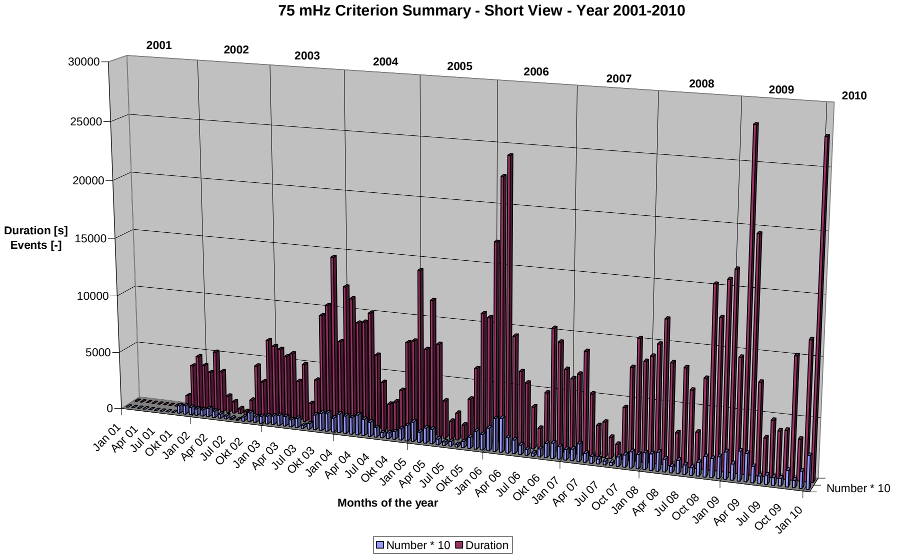
Impact of Market Opening & Change of Schedules



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Current Demands:

- Definition of clear rules:
  - Grid Codes
  - Connection Rules
  - Prequalification Tests
- Improve cooperation between:
  - Operators
  - Manufacturers
  - Consultants, Universities

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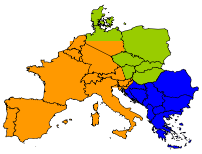
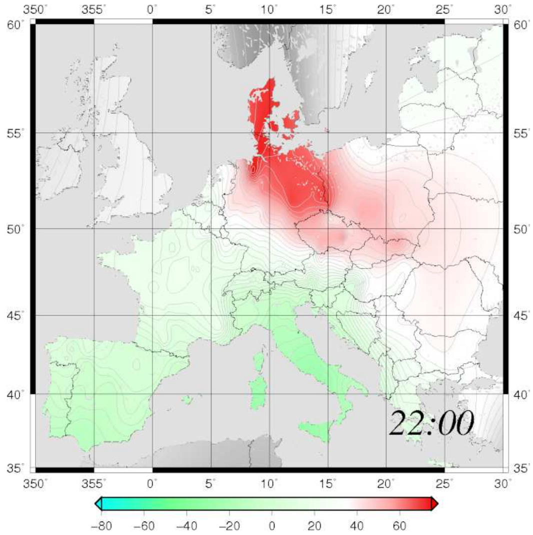
System State





Voltage Phase Angle (º)

Fig. D1a: Voltage phase angle differences in the UCTE system at 22:00 /ELES/

Source: UCTE Final Nov. 4th 2006 Event

Voltage Phase Angle- System Loading Finger Print

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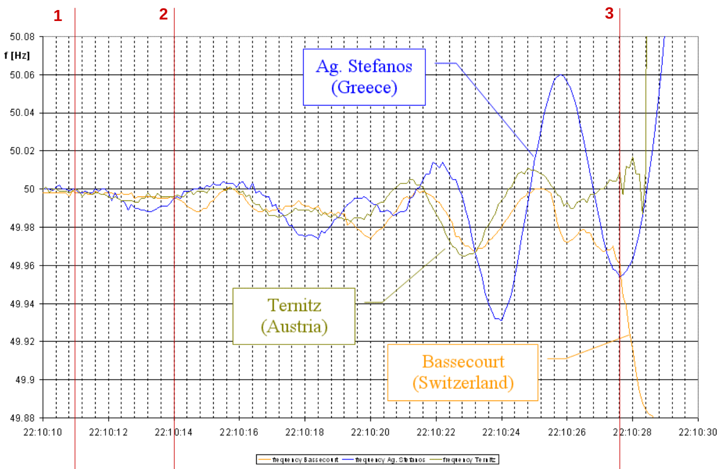
November 4th 2006 Event



1 – bb coupler

2 — first line

3 — instable

Fig. D3: Frequency of the three islands (Bassecourt-CH, Ag. Stefanos – GR, Ternitz-A during the system separation

Source: UCTE Final Report

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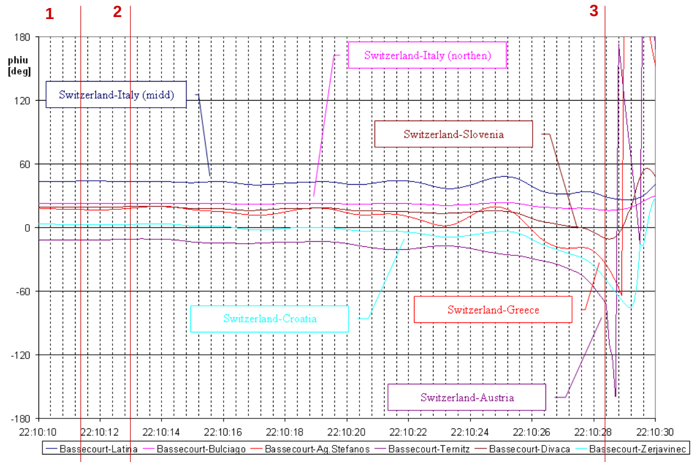
November 4th 2006 Event



1 – bb coupler

2 — first line

3 — instable

Fig. D4: Voltage phase angle differences of the three islands during the system separation (Bassecourt – CH, Latina - midd I, Bulciago-northern I, Ternitz – A, Divaca – SLO, Zerjavinec HR)

Source: UCTE Final Report

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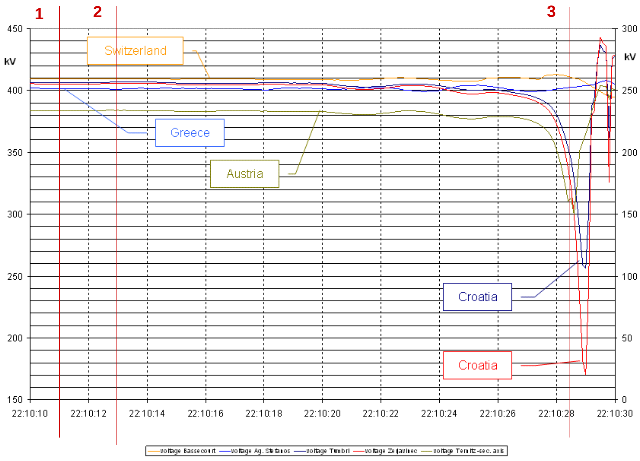
November 4th 2006 Event



1 – bb coupler

2 — first line

3 — instable

Fig. D6 Voltages far and near the North-South separation line during the system separation,(Bassecourt – CH, Ag. Stefanos – GR, Tumbri – HR, Zerjavinec – HR Ternitz - A

Source: UCTE Final Report

Content

Transient Stability Calculations

1. Analysis & reproduction of extreme system conditions
2. Calculations with the help of system models

- Check of protection settings
- Check of operation strategies, operation rules
  - System expansions, system topology changes
  - Power plant connections
  - Simulation of power system restoration schemes

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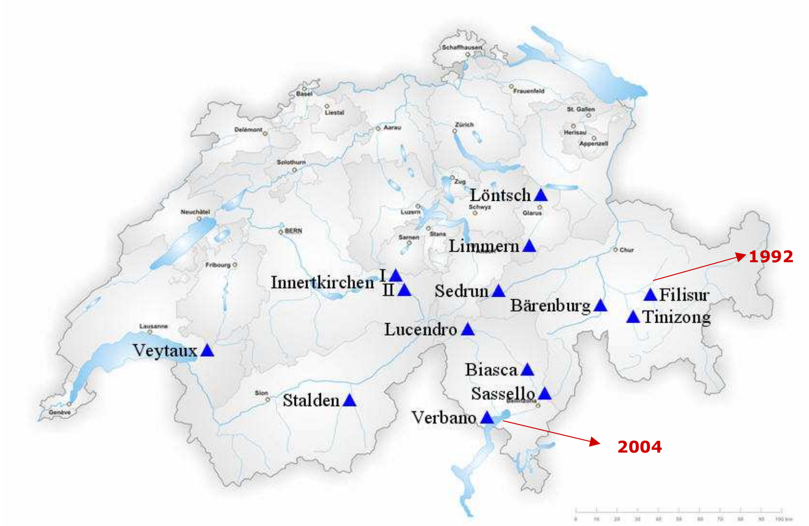
Detailed PP-Measurements



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Specific Power Plant Selection

Kraftwerk	Gesellschaft	Leistung / MVA	Turbine	T-Regler	AVR
Filisur	EGL / ALK	2x36.5	Francis		
Sassello	EGL / Cal.	2x13.5	Pelton	Mipreg	
Bärenburg	NOK / KHR	4x67.5	Francis	Vevey	ABB
Löntsch	NOK	2x37.5	Francis	ERW	ABB
Innertkirchen 1	BKW / KWO	5x52	Pelton	E.Wyss	MFO
Biasca	Atel / OIB	4x80	Pelton	ERW	ABB
Stalden	EGL / KWM	2x100	Pelton	Mipreg	ABB
Limmern	NOK / KLL	3x100	Pelton	ERW	BBC
Innertkirchen 2	BKW / KWO	2x37.5	Francis	DTL	ELIN
Veytaux	EOS / FMHL	4x75	Pelton	Mipreg	ABB
Lucendro	Atel	2x30	Pelton	DTL	Unitrol
Sedrun	NOK / KVR	3x60	Pelton	DTL	RTA
Tinizong	EWZ	2x26, 1x18	Pelton	ETR	Unitrol
Verbano	Atel / Ofima	4x32	Francis	DTL	Siemens

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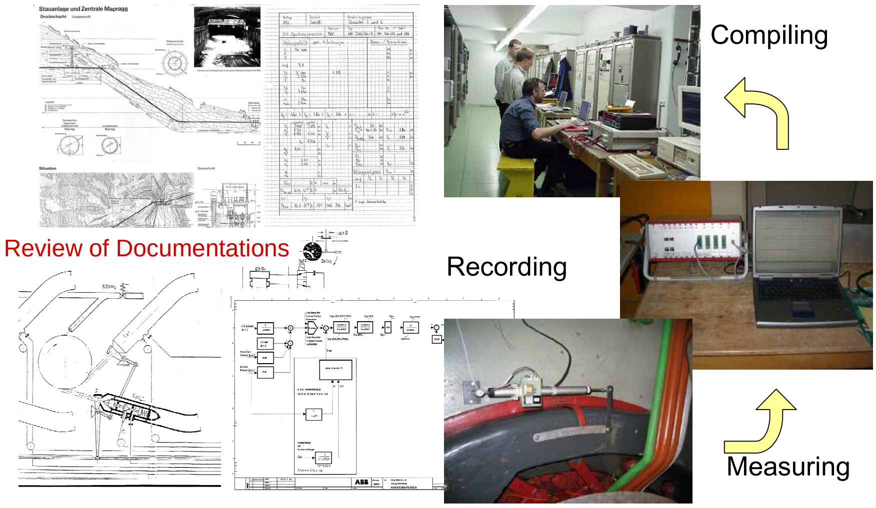
Documentation + Measurements = Dynamic Model



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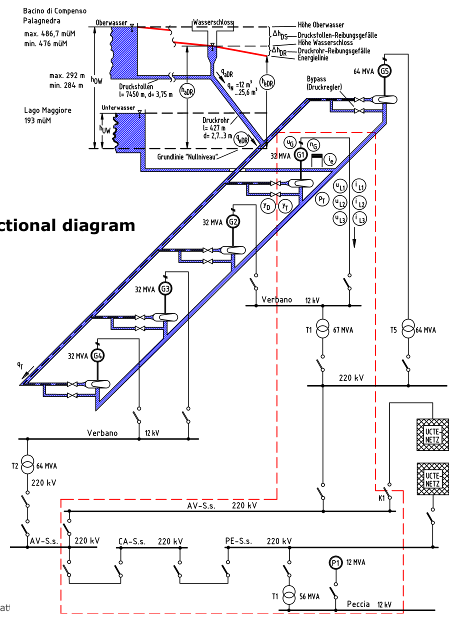
Measurements Francis Turbine – Verbano PP

PP functional diagram



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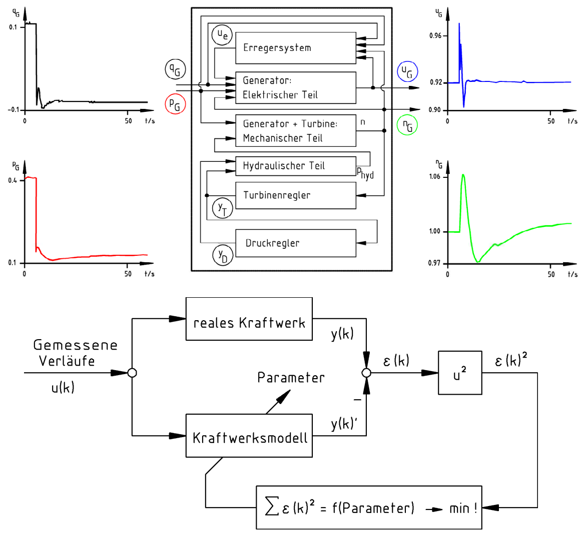
Parameter Identification Principle



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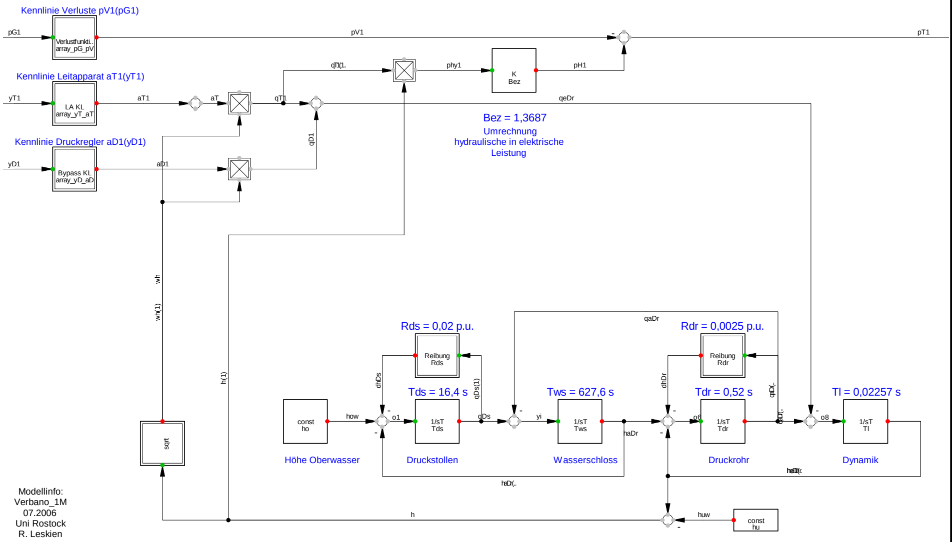
a) Hydraulic System – Block Diagram



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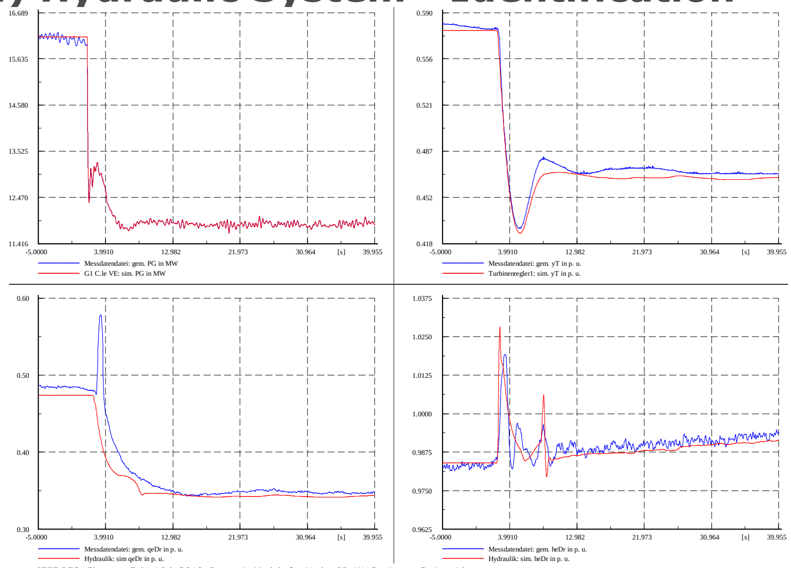
a) Hydraulic System - Identification



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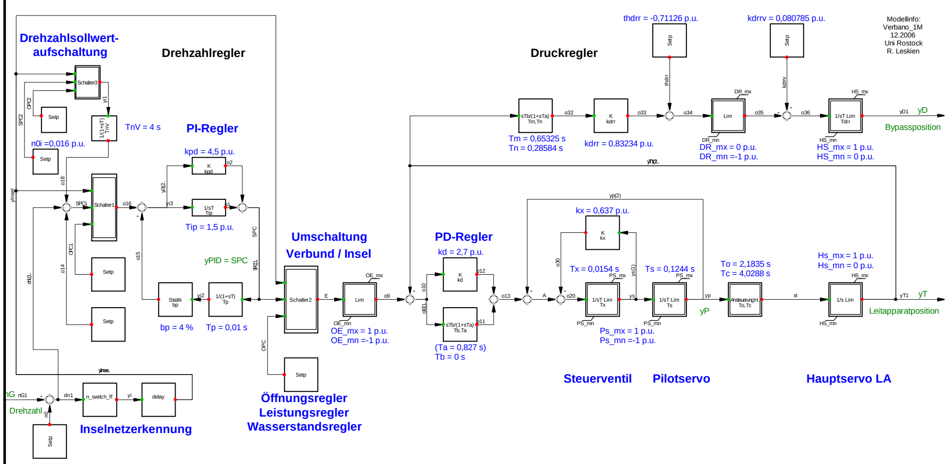
b) Turbinen Controller – Block Diagram



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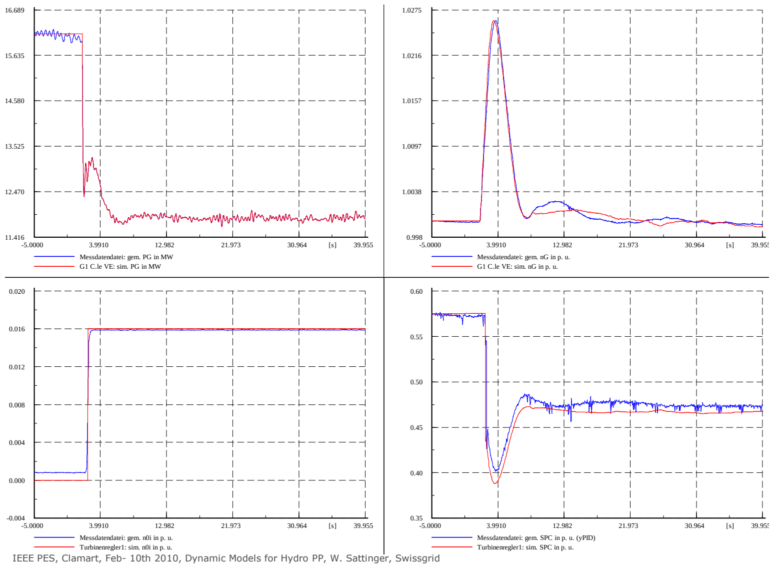
b) Turbine Controller – Identification 1/2



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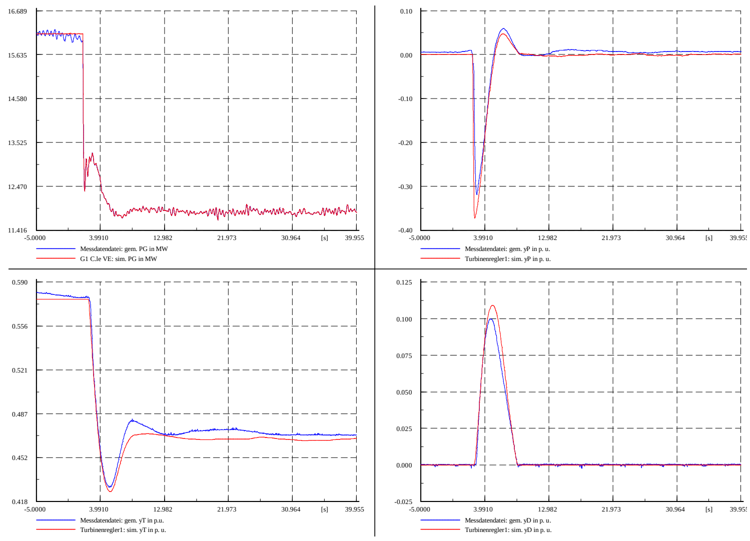
b) Turbine Controller – Identification 2/2



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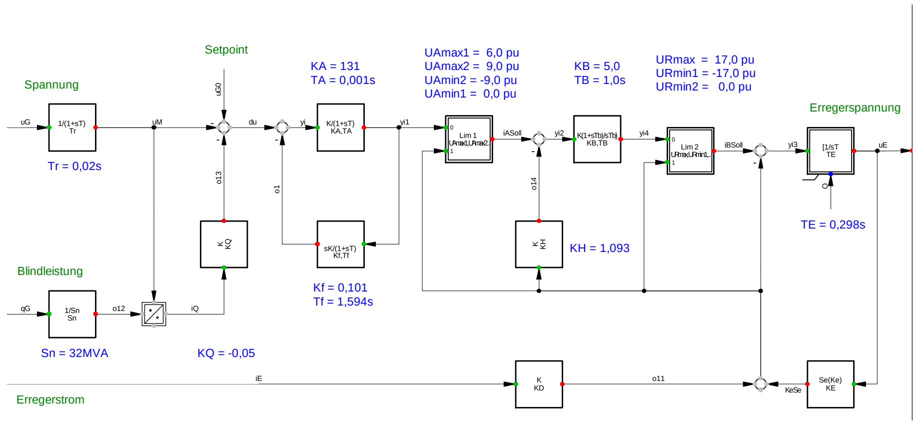
c) Voltage Controller – Block Diagram



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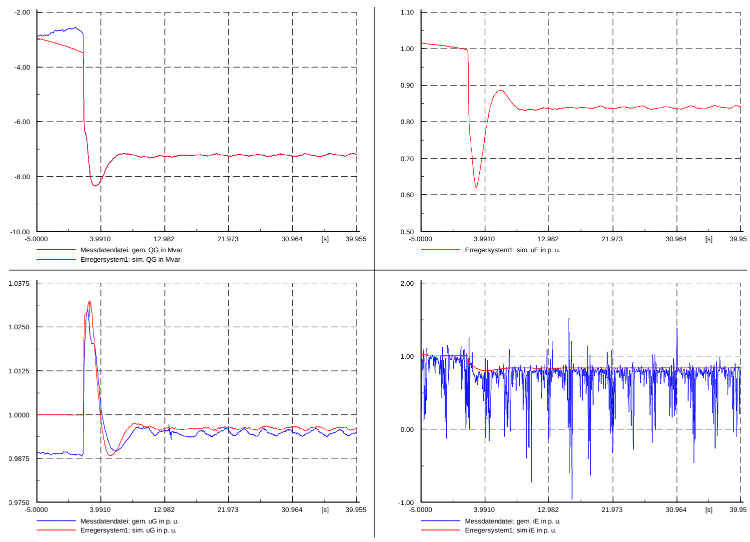
c) Block Diagram - Identification



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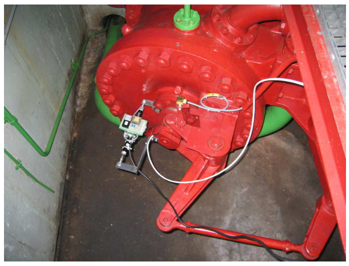
Impressions – Verbano PP Measurements



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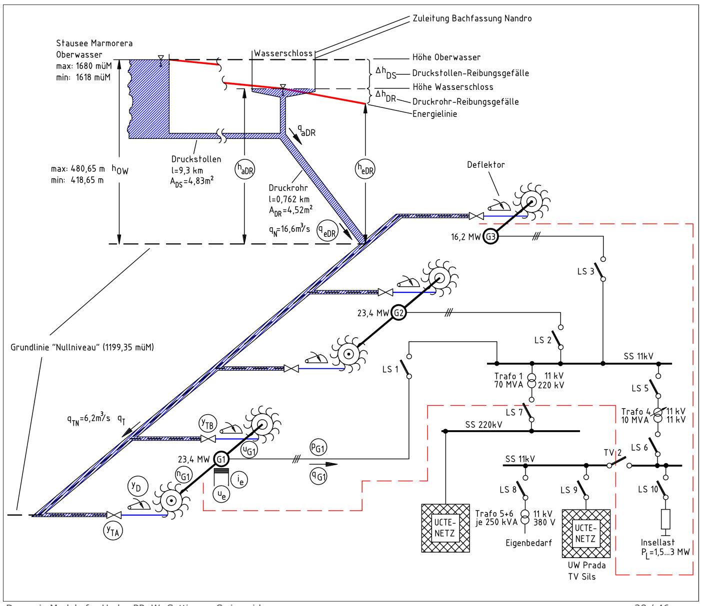
Measurement Pelton Turbine

Tinizong PP



Functional Diagram

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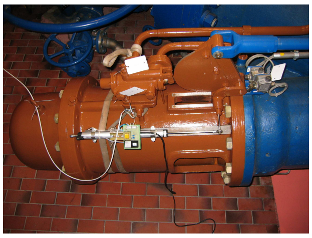
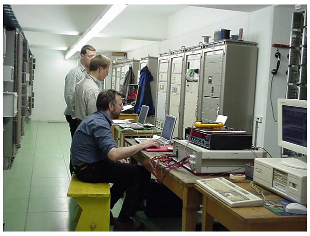
Convert – Record - Compute





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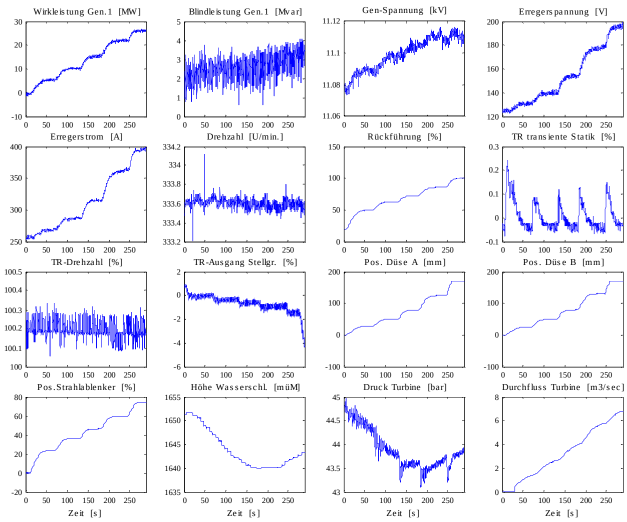
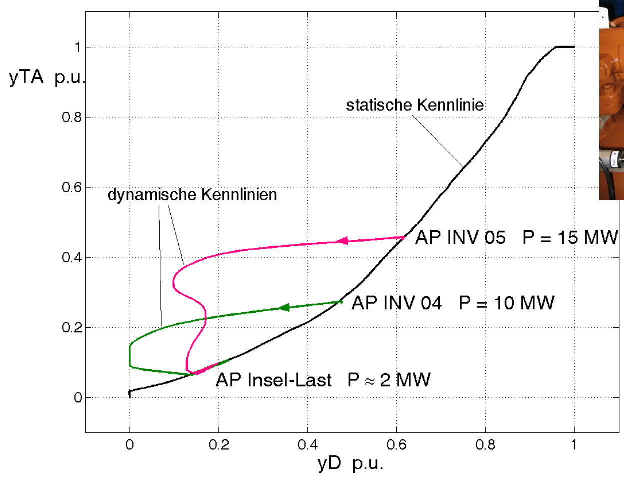
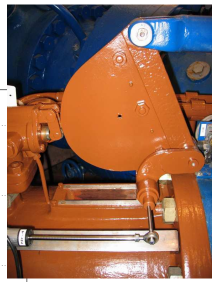
Steady-State Measurements for Characteristic Acquisition

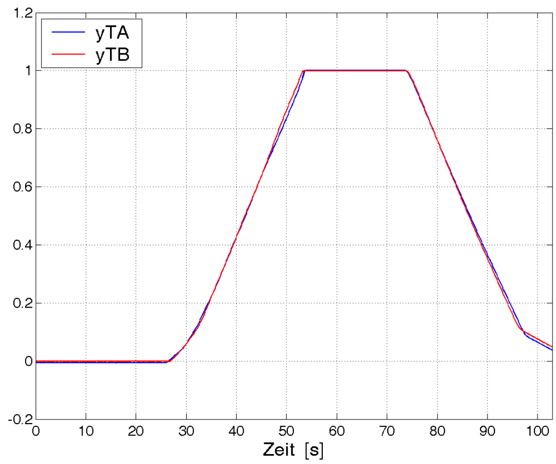


Impact of Nonlinearities





Measurement of Valve Opening and Close Speed



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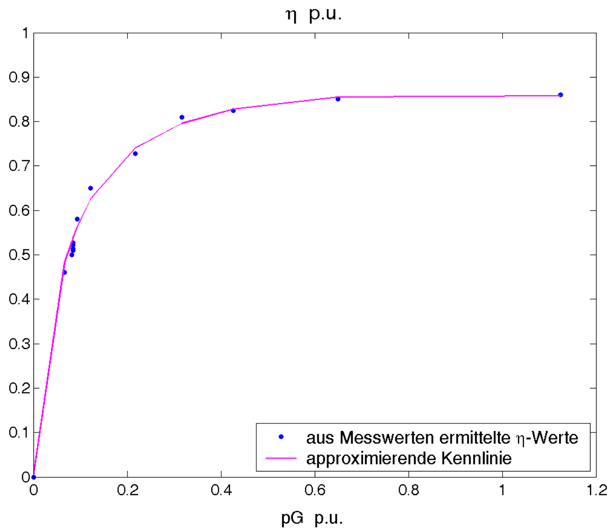
Efficiency Measurement



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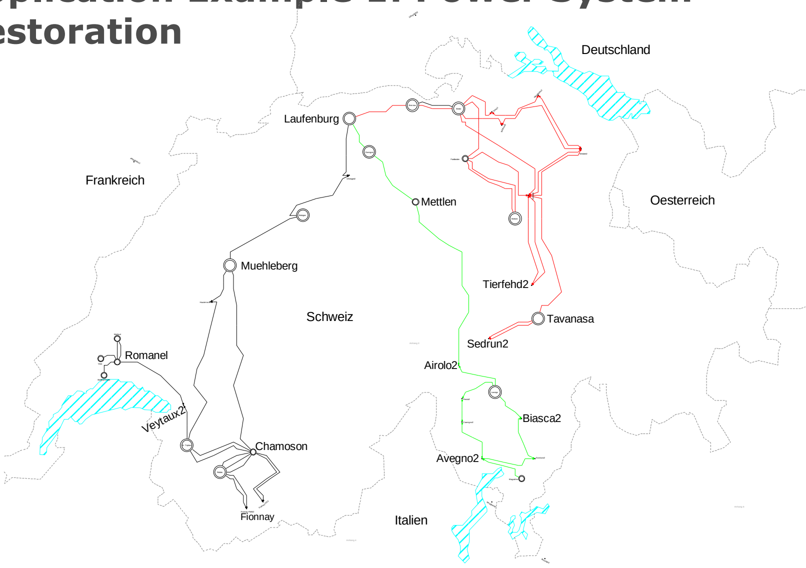
Application Example 1: Power System Restoration



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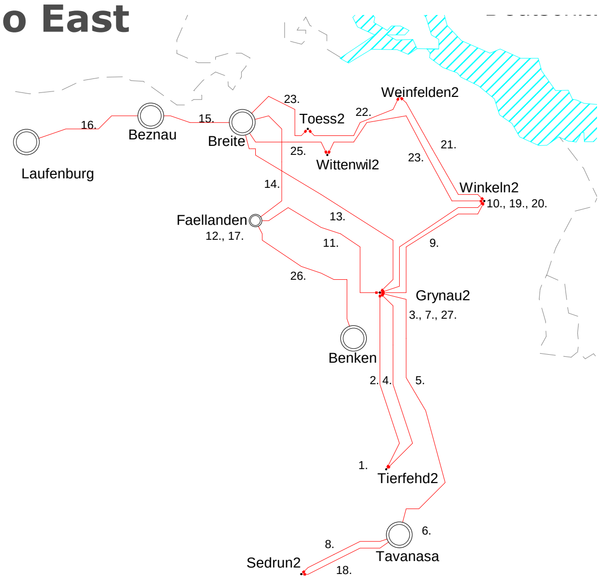
Szenario East



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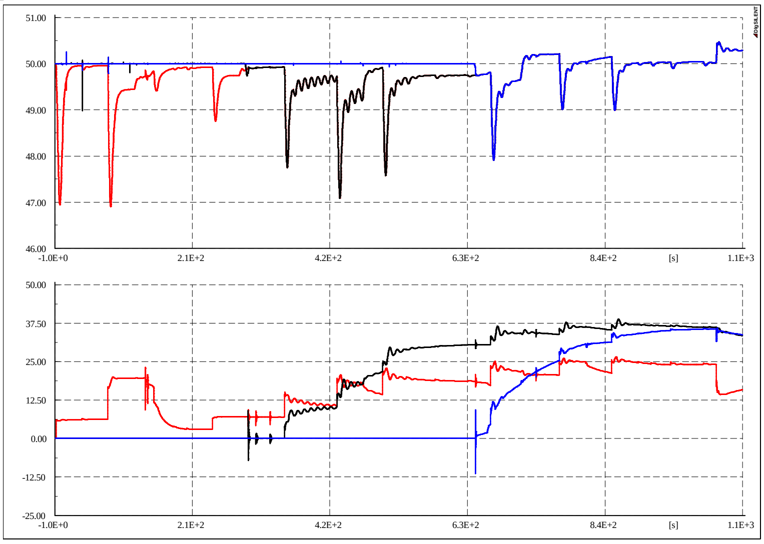
Frequencies & Active Power



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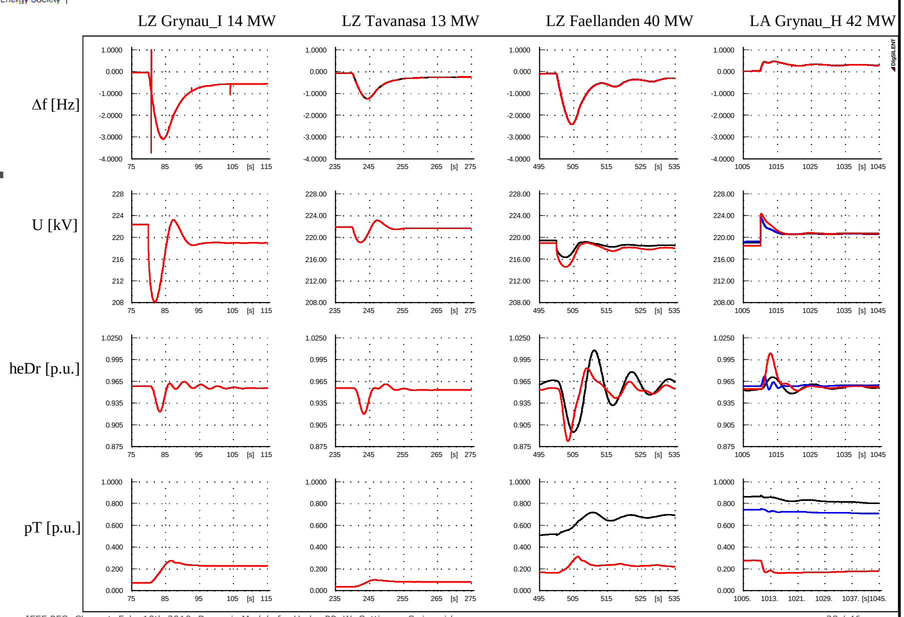
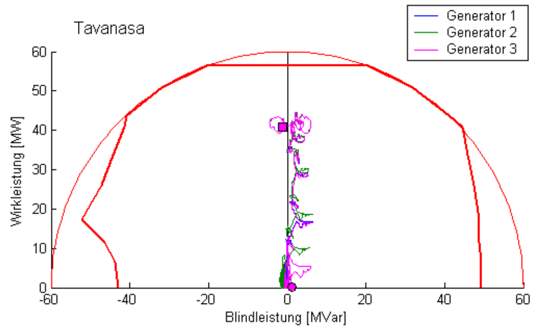
Connection Steps

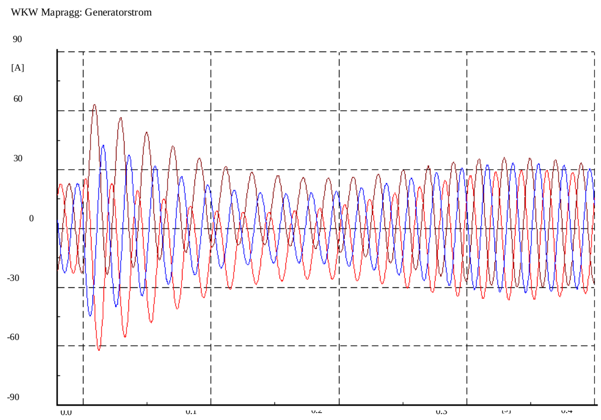


Check of Protection Settings



Application Example 2: Check of Synchrocheck Settings, Calculation of UFLS Settings

Example: Stator currents Mapragg generator after connection of Mapragg-Bonaduz (25°) line



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Dynamic Calculations in Order to Check the Synchrocheck Settings

- Synchrocheck device:
  - Protect PP and system equipment against mechanical stress
  - too restrictive settings might limit system operation flexibility

- Check & Optimisation of Synchrocheck Settings with the help of dynamic model calculations:
  - Extend Swiss dynamic model
  - Define admissible limits
  - Calculation of maximal settings based on simulation calculations of extreme situations

  ➢ Admissible generator/turbine active power step < 0.5 rated power

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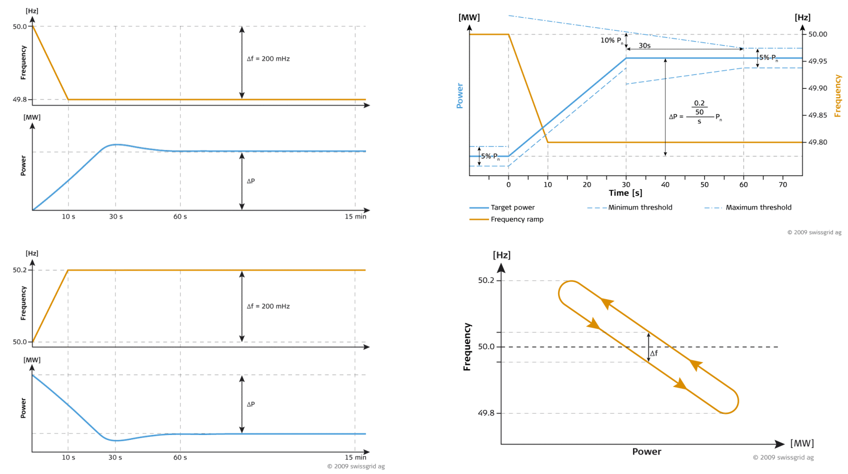
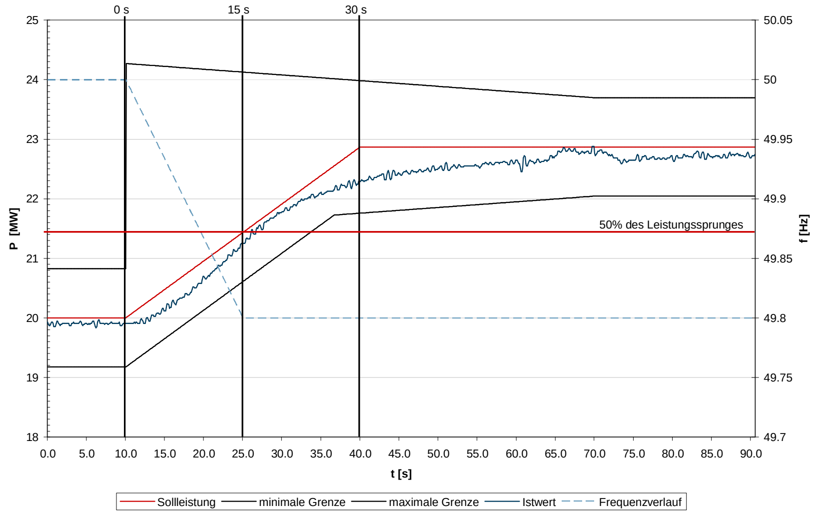
Application Example 3: Perform Prequalification Tests



see: http://www.swissgrid.ch/power_market/grid_operation/ancillary_services/prequalification/document/D091111_test-for-primary-control-capability_V1R0.pdf?set_language=en

Prequalification Tests Results



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Conclusion & Outlook

- Increased importance of dynamic modelling
- Planned and ongoing model expansions and improvements
  - Further model calibration with the help of WAM measurements
  - Model reduction -> real-time / Training simulator
    (no IEEE Standard models!)
- Dynamic model exchange with neighbouring TSOs
- Coupling of steady-state data from the SCADA/EMS system with dynamic data -> near real-time system analysis
- Database with solved dynamic cases -> dynamic system planning / ahead dynamic calculations

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Thank you for your attention!

Questions?