THE NORDIC TEST SYSTEM FOR VOLTAGE STABILITY ASSESSMENT

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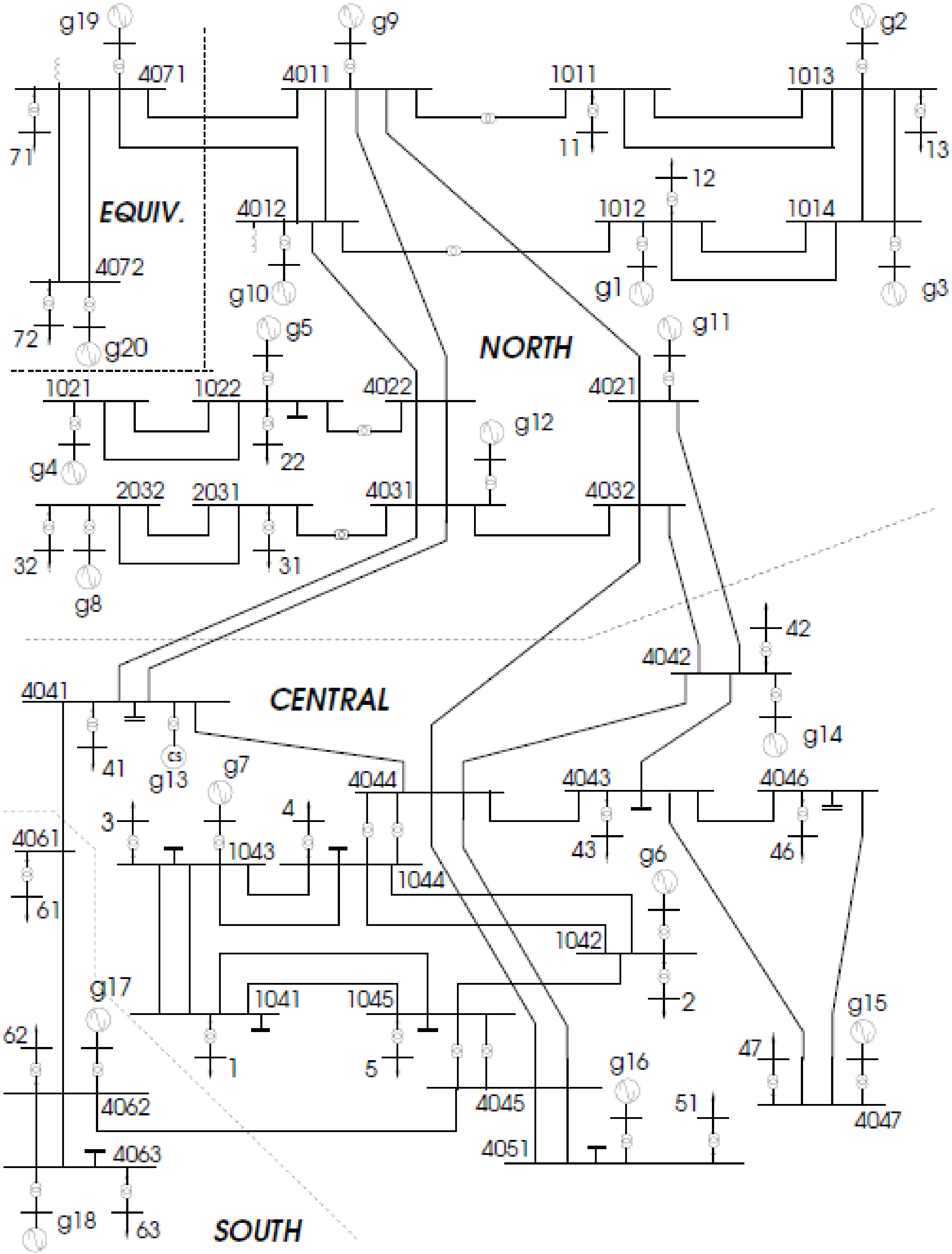
Context

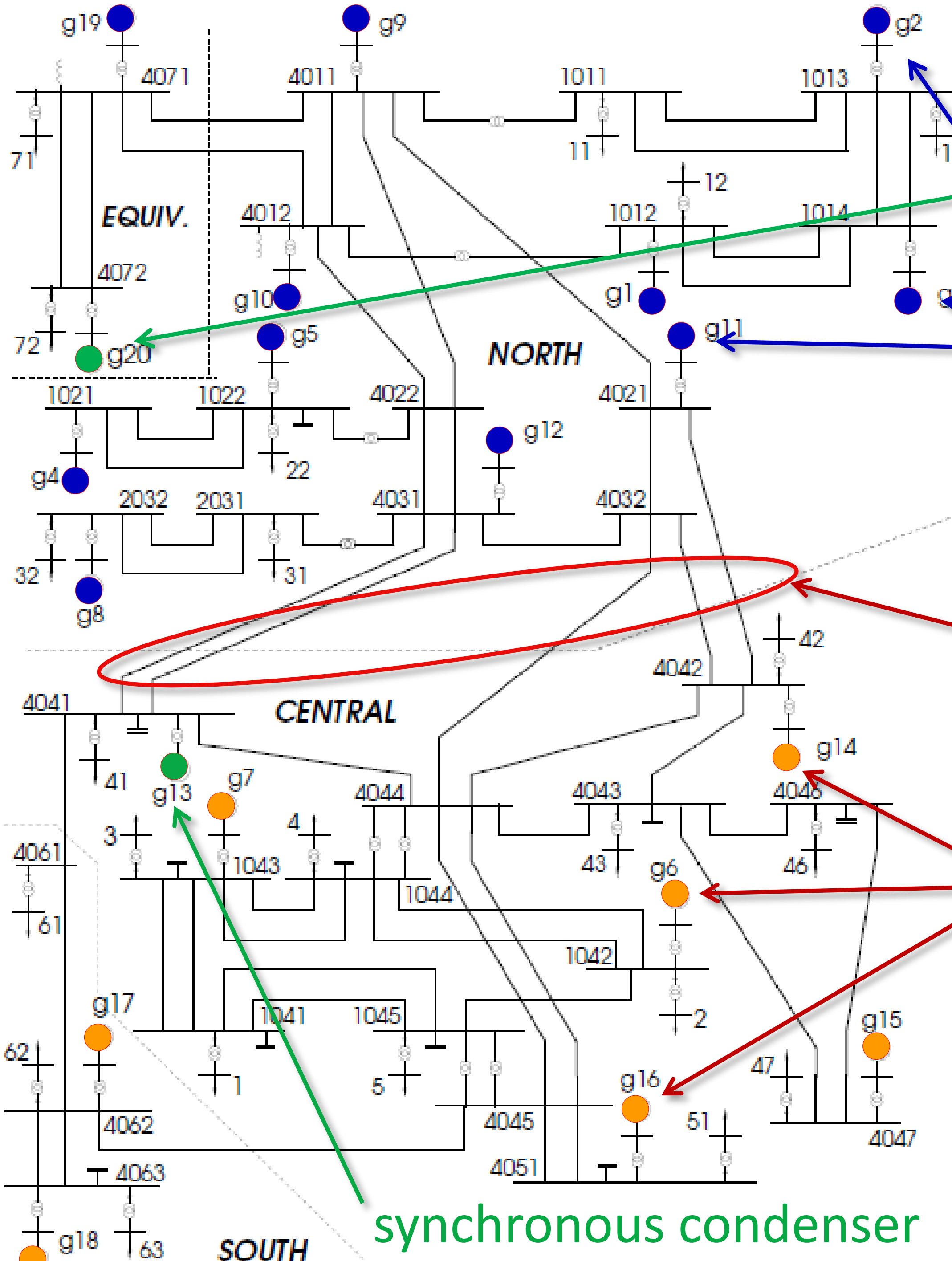
- One of the two systems prepared by the Task Force on « Test Systems for Voltage Stability and Security Assessment »
  - under the auspices of Power System Stability Sub-committee
- modified version of a so-called “Nordic32” system
  - proposed in 1995 by a CIGRE WG
- focus is on long-term voltage stability
  - system evolution over several minutes after a disturbance
  - system also exposed to short-term (angle) instability

Contents

- **System overview**
- Modelling
- Dynamic responses to disturbances
- Preventive voltage security assessment
- Corrective (post-disturbance) control



- transmission : 400 & 220 kV
- sub-transmission : 130 kV
- 50 Hz system
- 74 buses
- 20 generators
- 102 branches, including
  - 20 step-up transformers
  - 22 distribution transformers



large, equivalent gener.

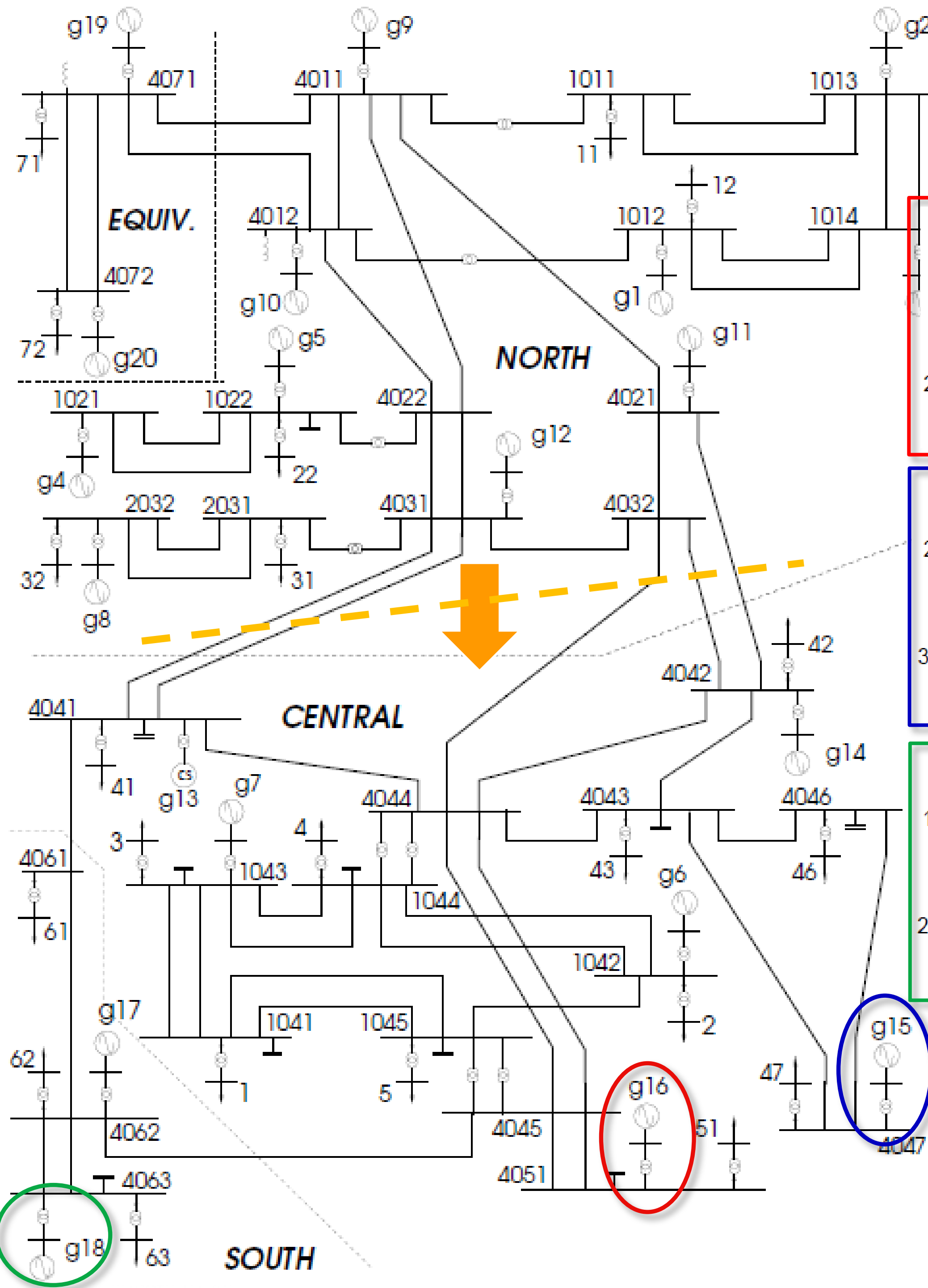
hydro units -
primary frequency control

long, series-compensated
400-kV lines

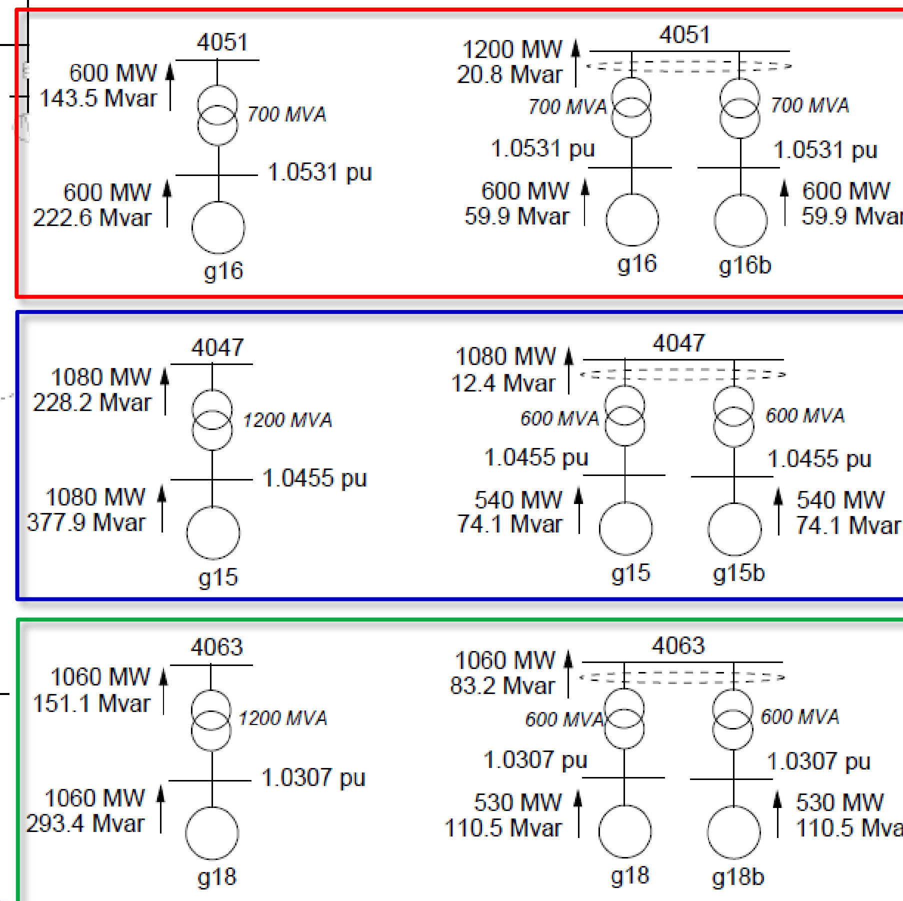
thermal units -
constant mechanical power

synchronous condenser

IEEE



oper. point A   oper. point B

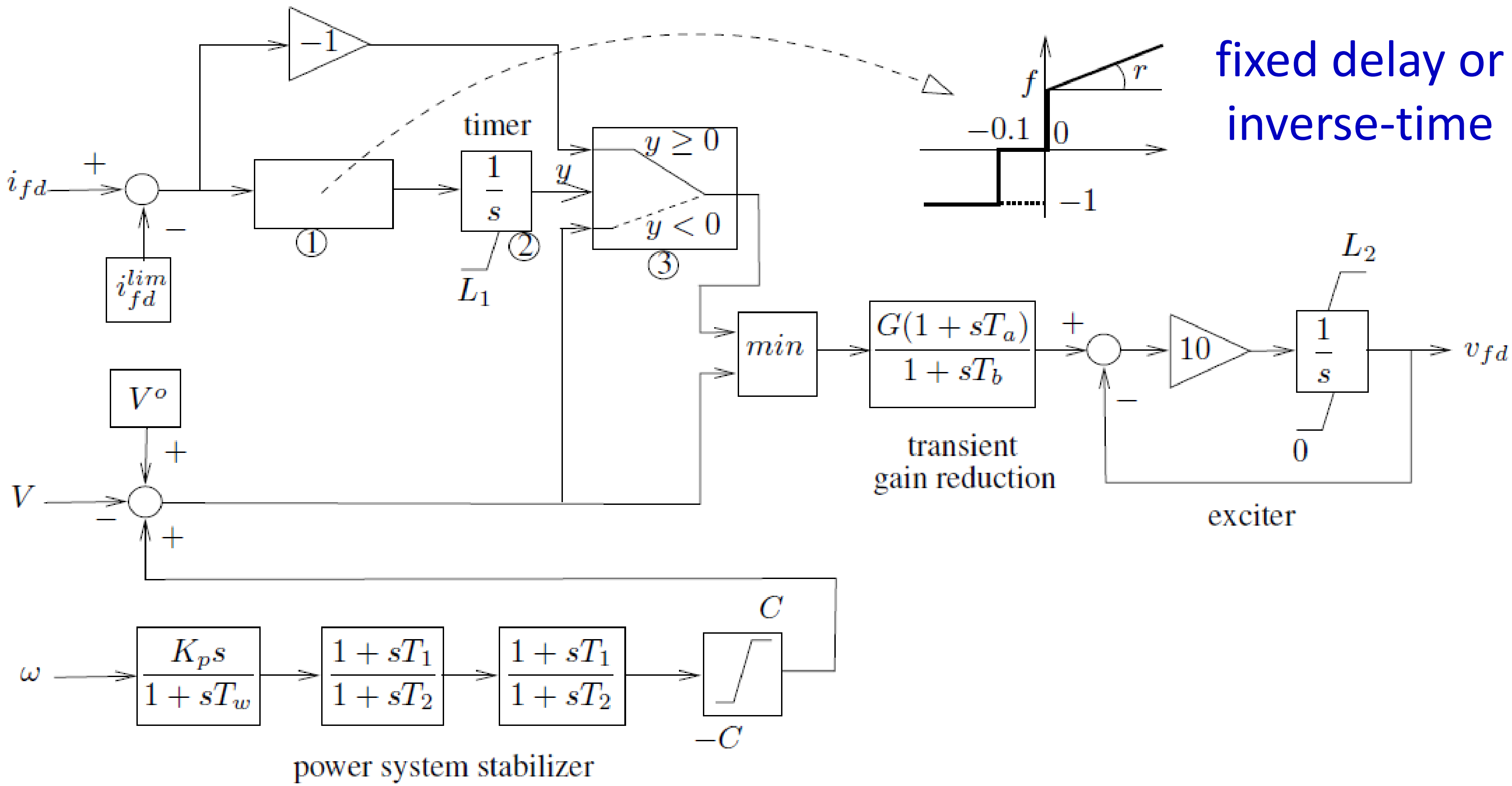


Dynamic security assessment

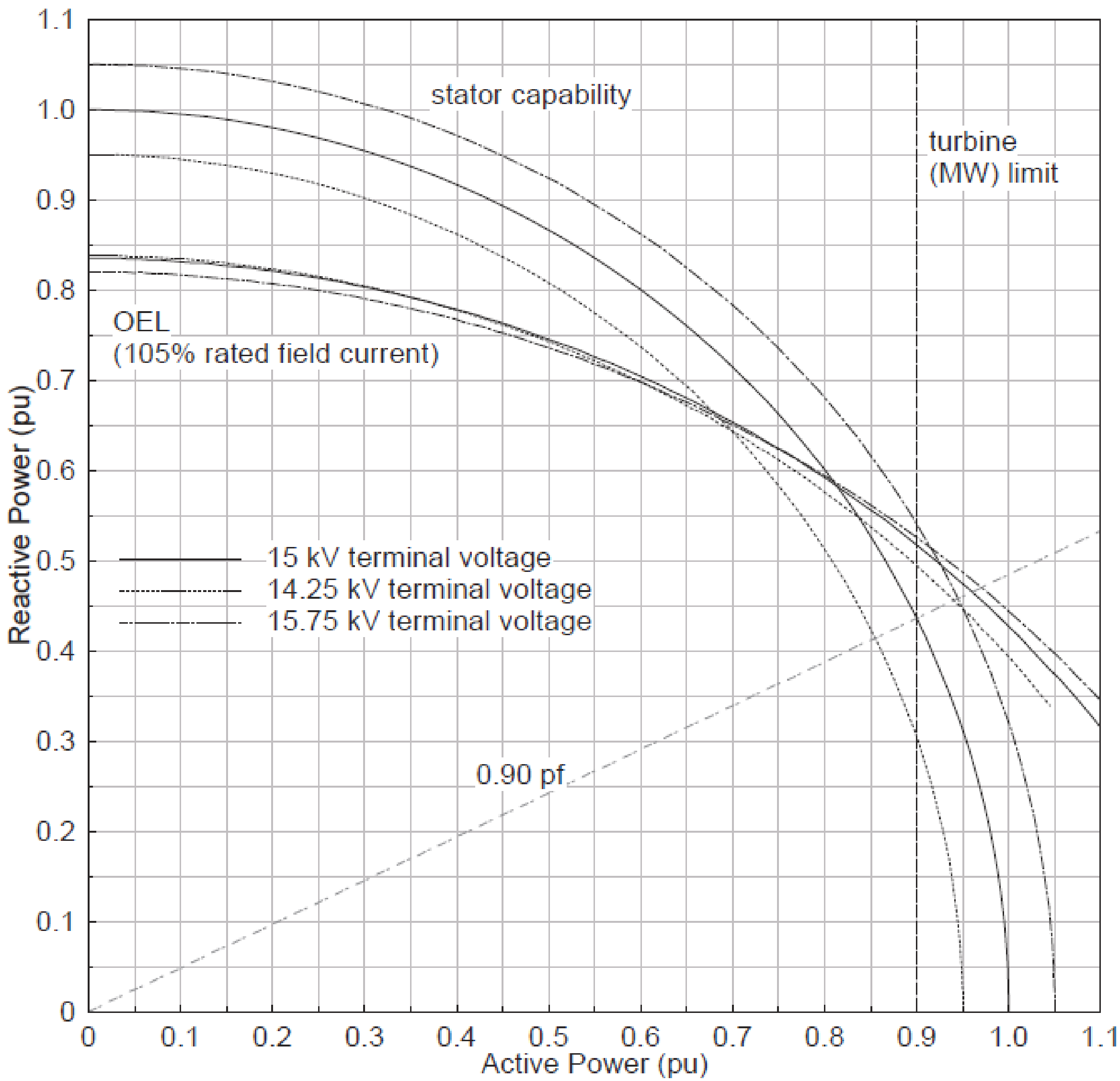
- Operating point A : very insecure
  - several single contingencies cause instability
  - even some transient angle instability cases
- Operating point B : secure
  - the system can stand a 5-cyle (0.1 s) fault on any line, cleared by tripping the line
  - the system can stand the outage of any single generator
- Criteria used in long-term dynamic simulation
  - all distribution voltages restored into their deadband by Load Tap Changers (⇒ all load powers restored)
  - no loss of synchronism
  - no generator has its terminal voltage settling below 0.85 pu

Contents

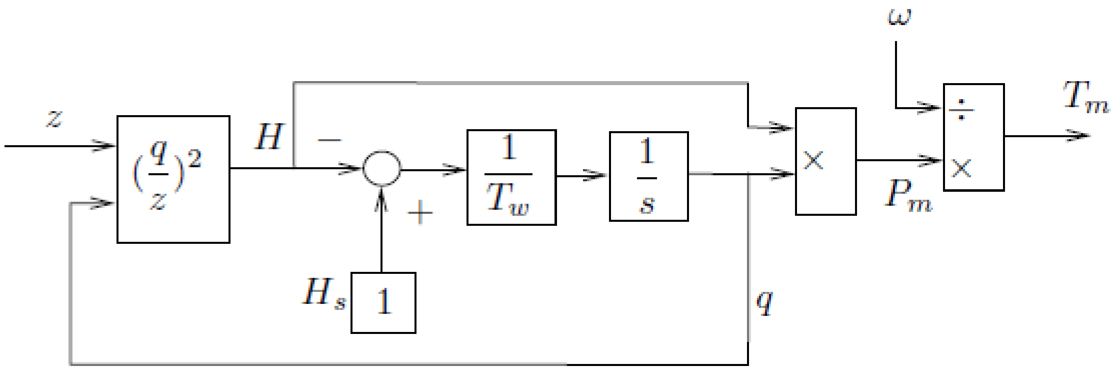
Exciter, AVR, PSS and OverExcitation Limiter (OEL)



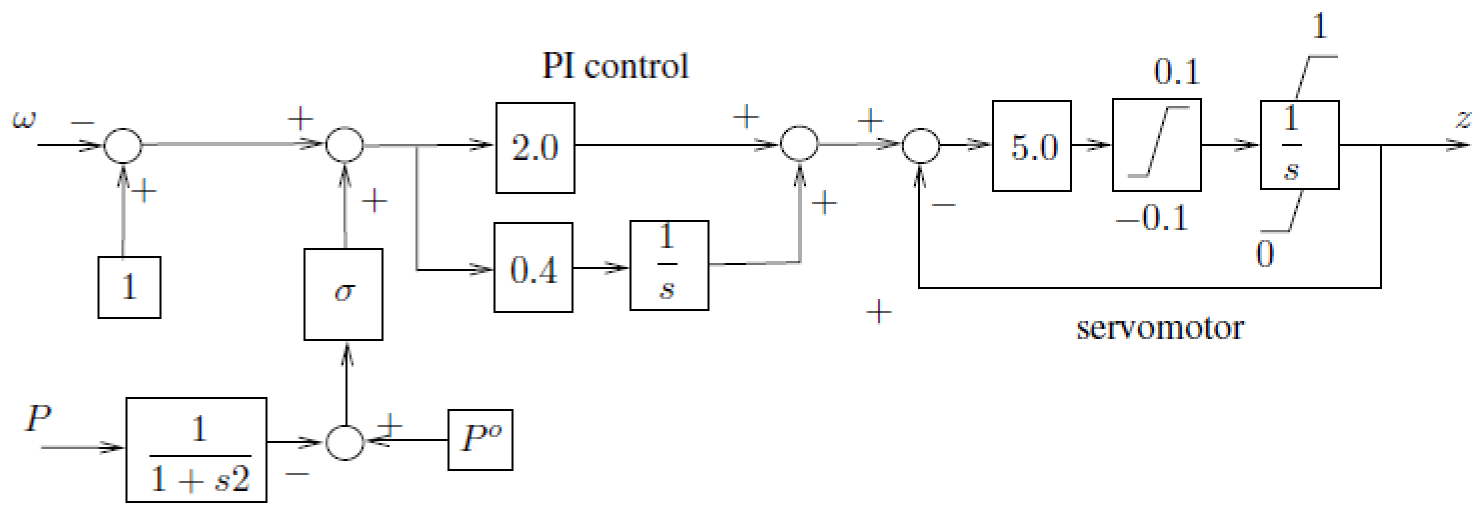
Capability curves of round-rotor generators for various terminal voltages



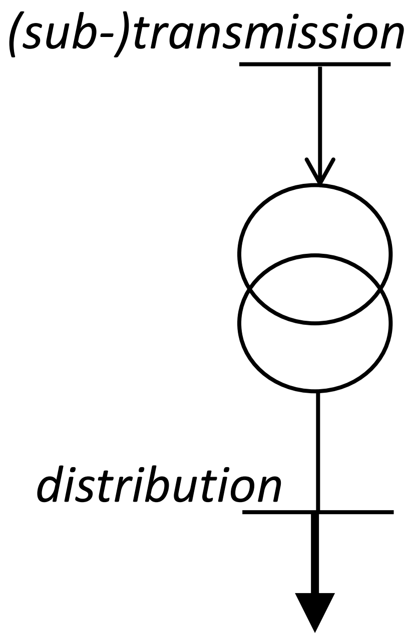
Hydro Turbine model



Speed-governor model



Load model



$$P = P_o(\frac{V}{V_o})^\alpha \quad Q = Q_o(\frac{V}{V_o})^\beta$$

Load Tap Changers (LTC):

- voltage deadband : [0.99 1.01] pu
- range of transformer ratio : [0.88 1.20] pu/pu
- 33 tap positions
- various tapping delays

transformer	delays	
	τ_1 (s)	τ_2 (s)
11-1011	30	8
12-1012	30	9
13-1013	30	10
22-1022	30	11
1-1041	29	12
2-1042	29	8
3-1043	29	9
4-1044	29	10
5-1045	29	11
31-2031	29	12
32-2032	31	8
41-4041	31	9
42-4042	31	10
43-4043	31	11
46-4046	31	12
47-4047	30	8
51-4051	30	9
61-4061	30	10
62-4062	30	11
63-4063	30	12
71-4071	31	9
72-4072	31	11

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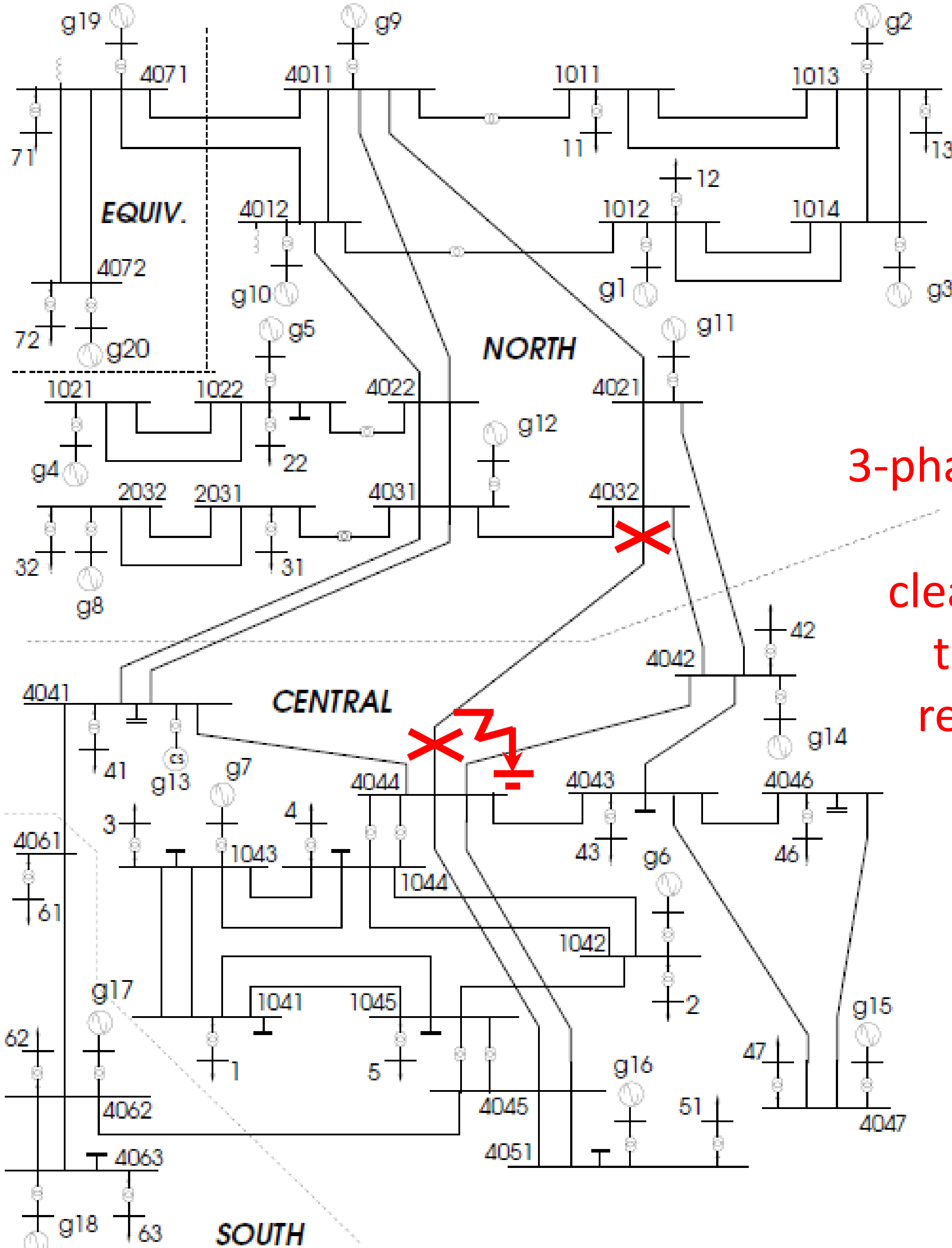
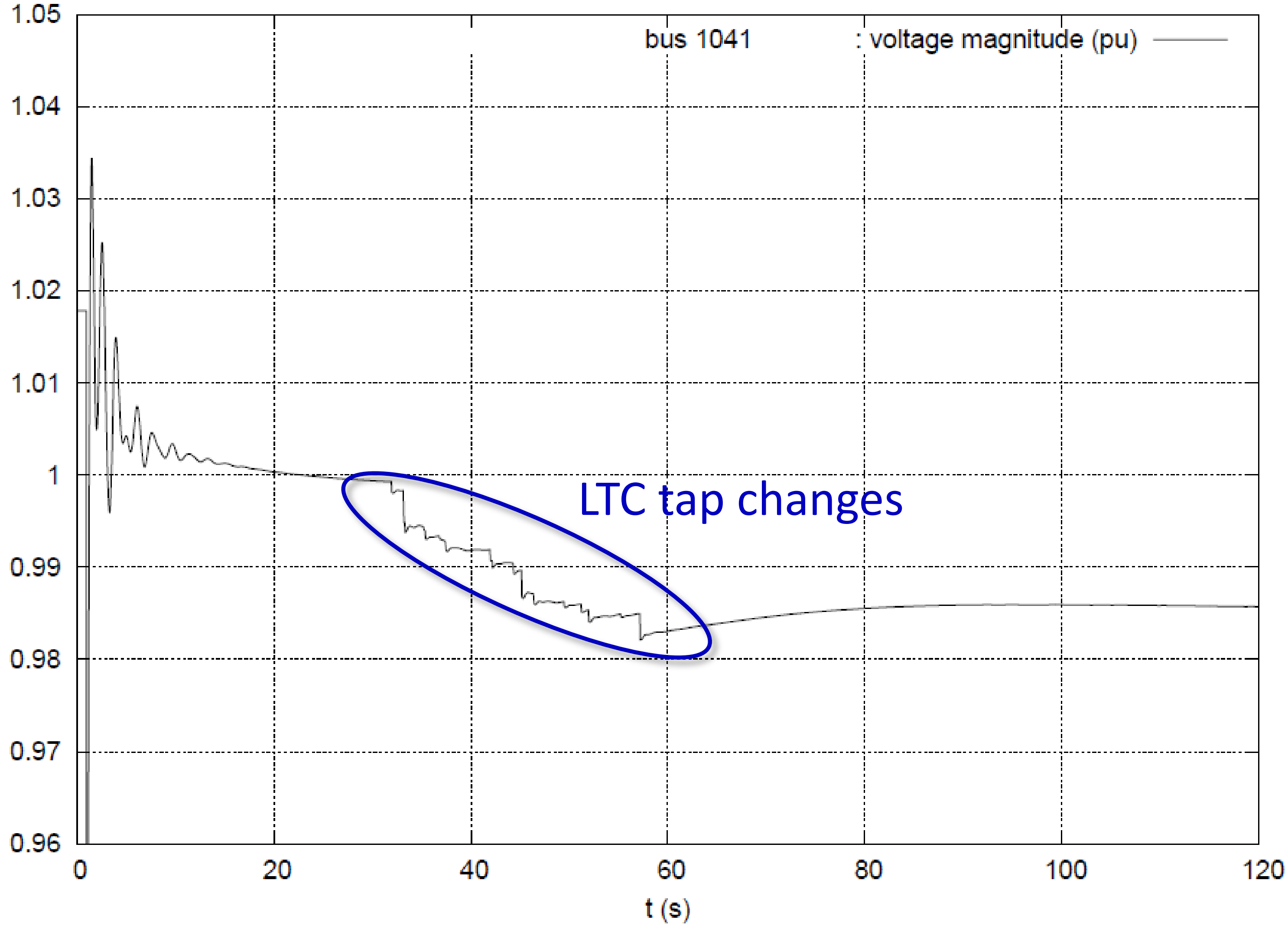
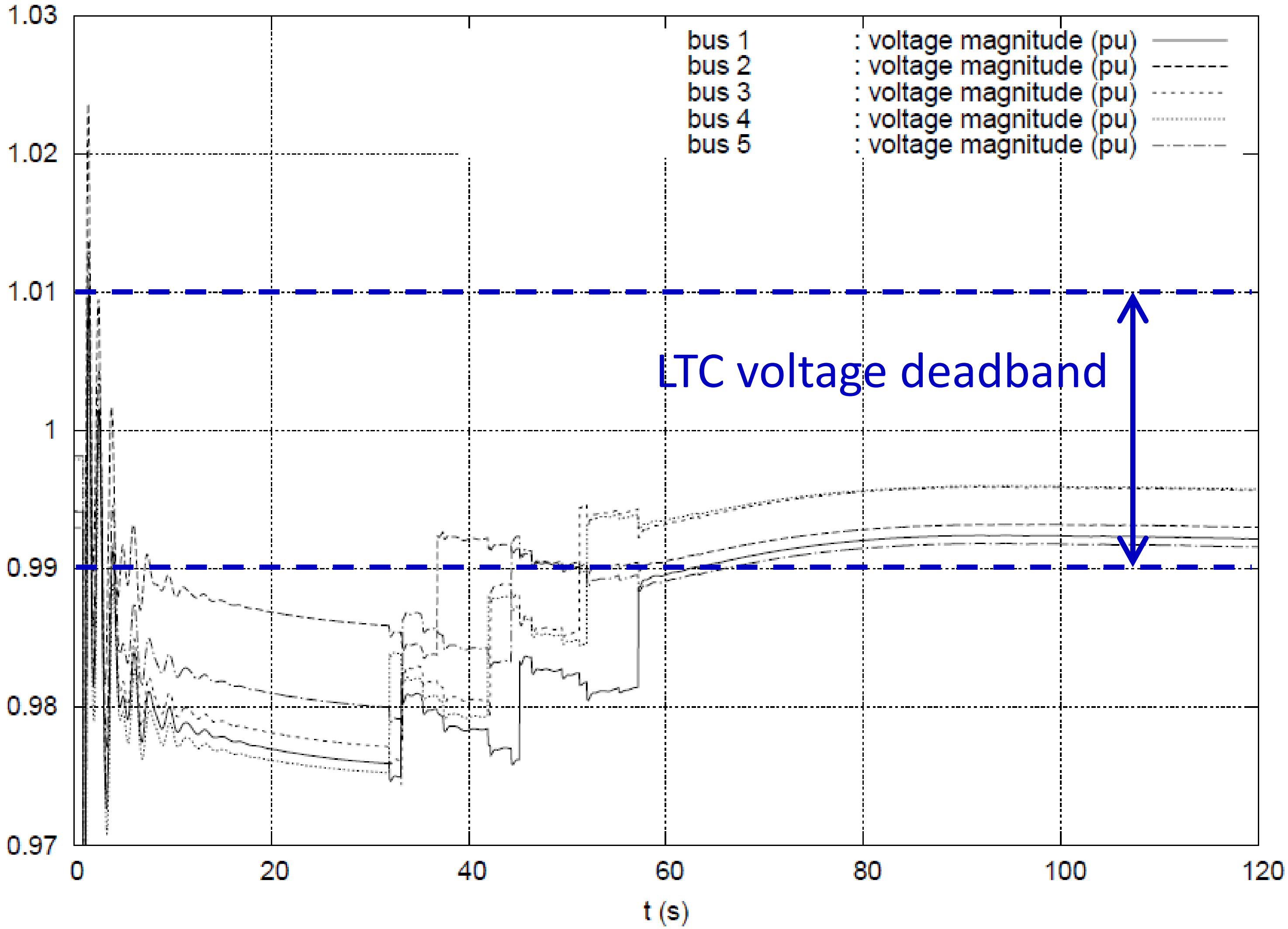


3-phase 5-cycle (0.1 s) fault cleared by opening the line, which remains opened

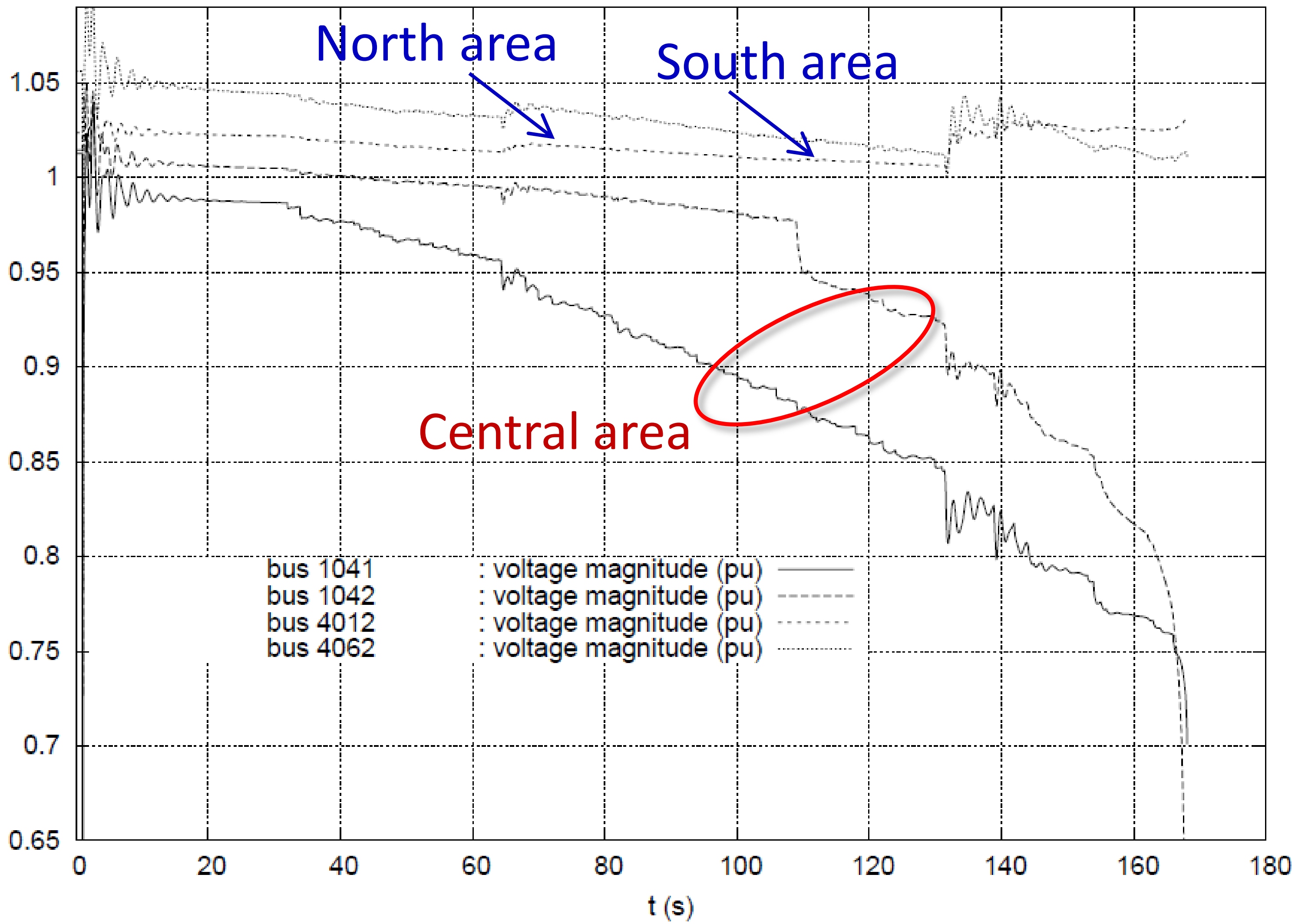
Secure oper. point B - Transmission voltage



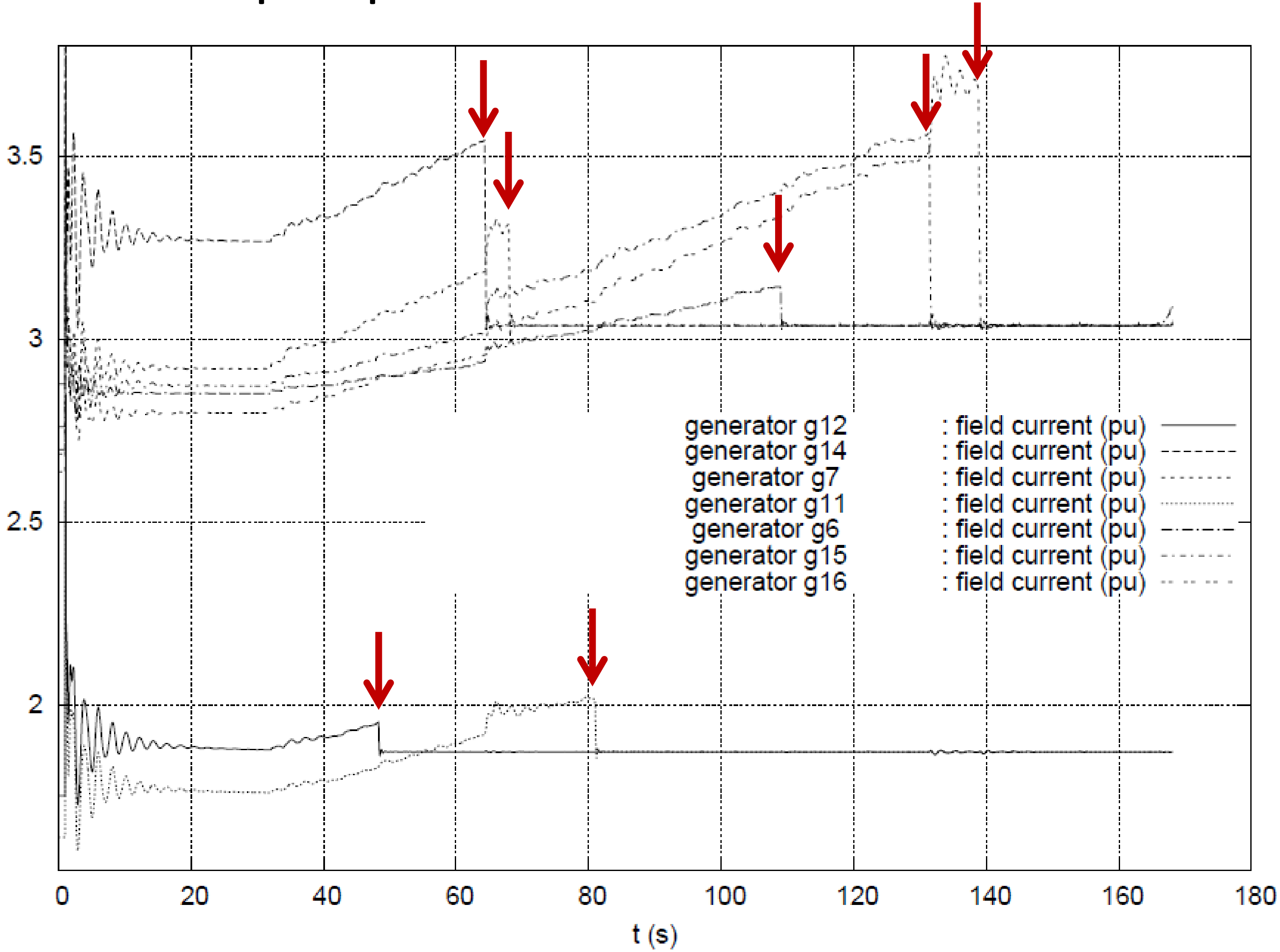
Secure oper. point B - Voltage at LTC-controlled distrib. buses



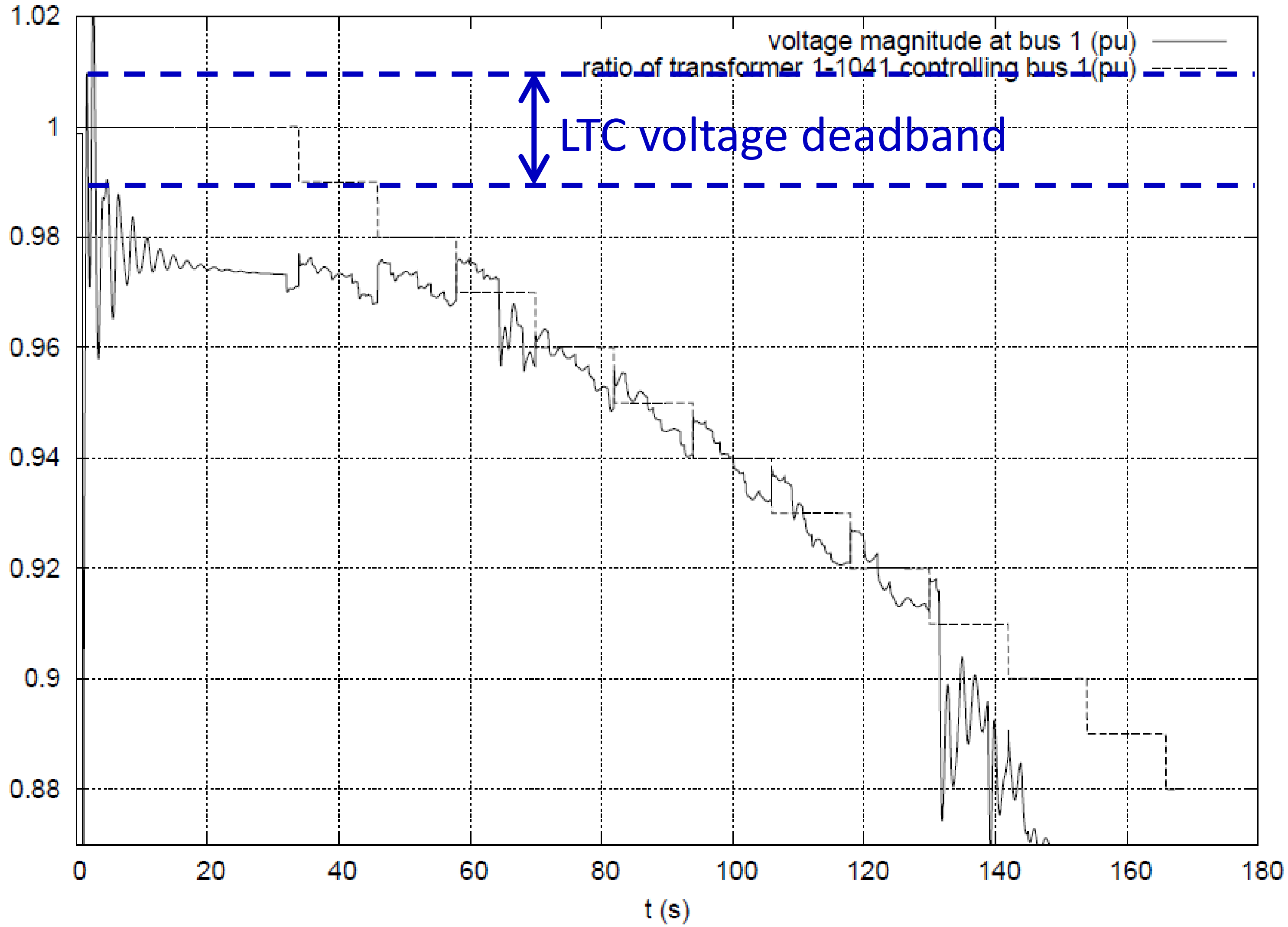
Insecure oper. point A - Transmission voltages



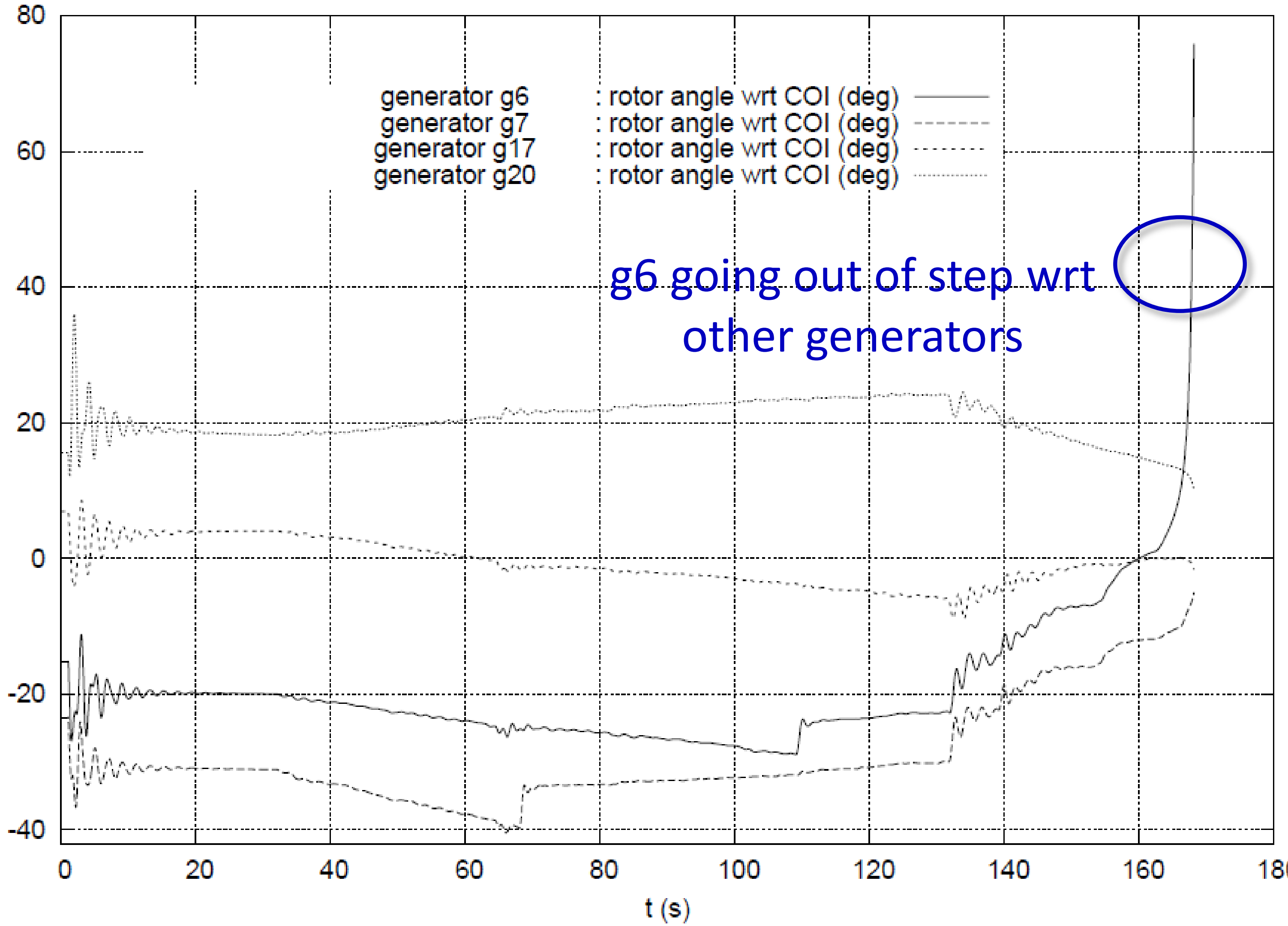
Insecure oper. point A - Generator field currents



Insecure op. point A - Voltage at LTC-controlled distrib. bus



Insecure op. point A - rotor angles (wrt center of inertia)



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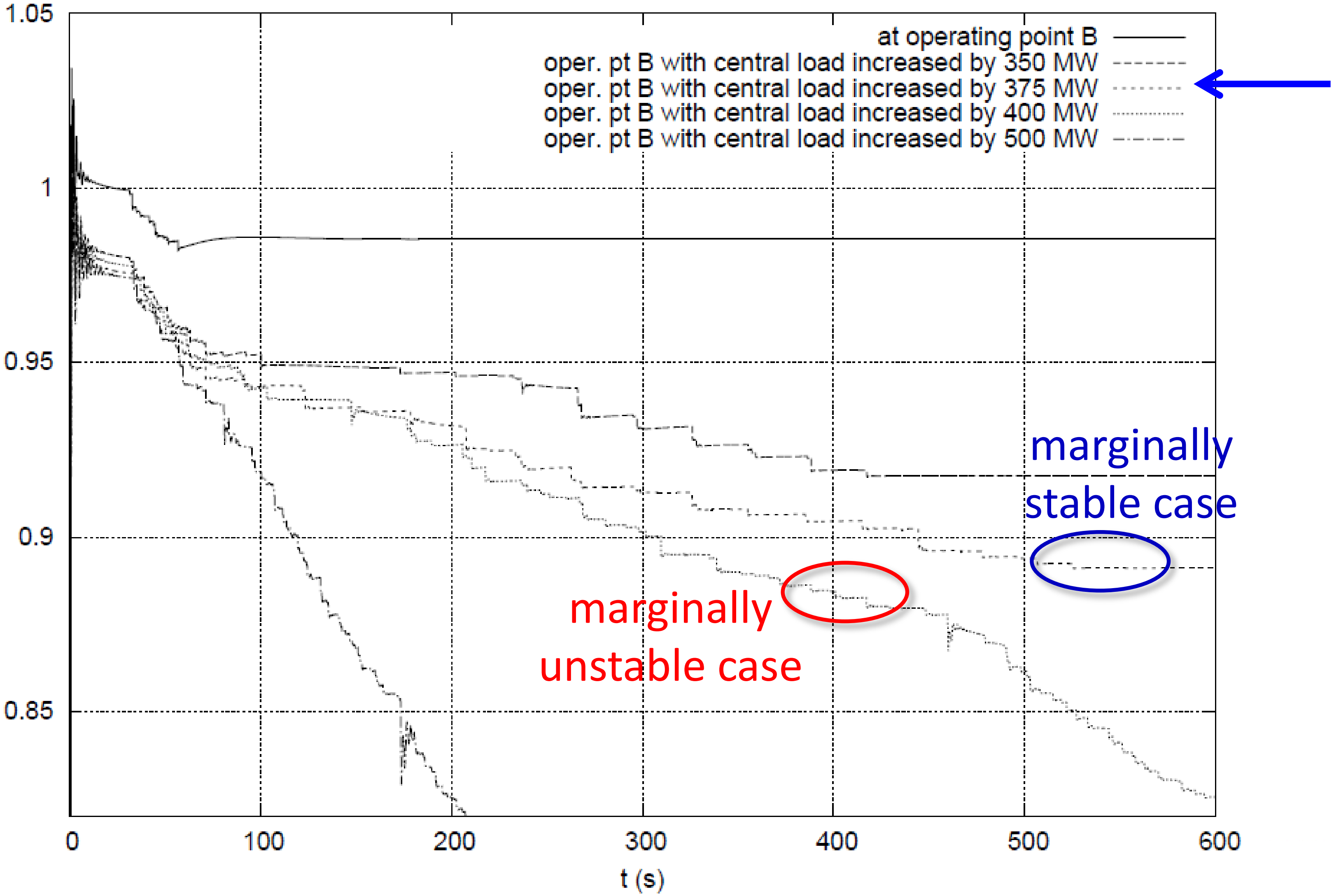
Secure Operation Limit (SOL)

- An SOL corresponds to the maximum « stress » that can be accepted *in the pre-contingency configuration* such that the system responds in a stable way to each of the specified contingencies
- stress = increase of load power in Central area
- tools :
  - power flow computations for various values of Central area load
  - long-term dynamic simulations to assess the system response to each contingency

Example of SOL determination - secure oper. pt B



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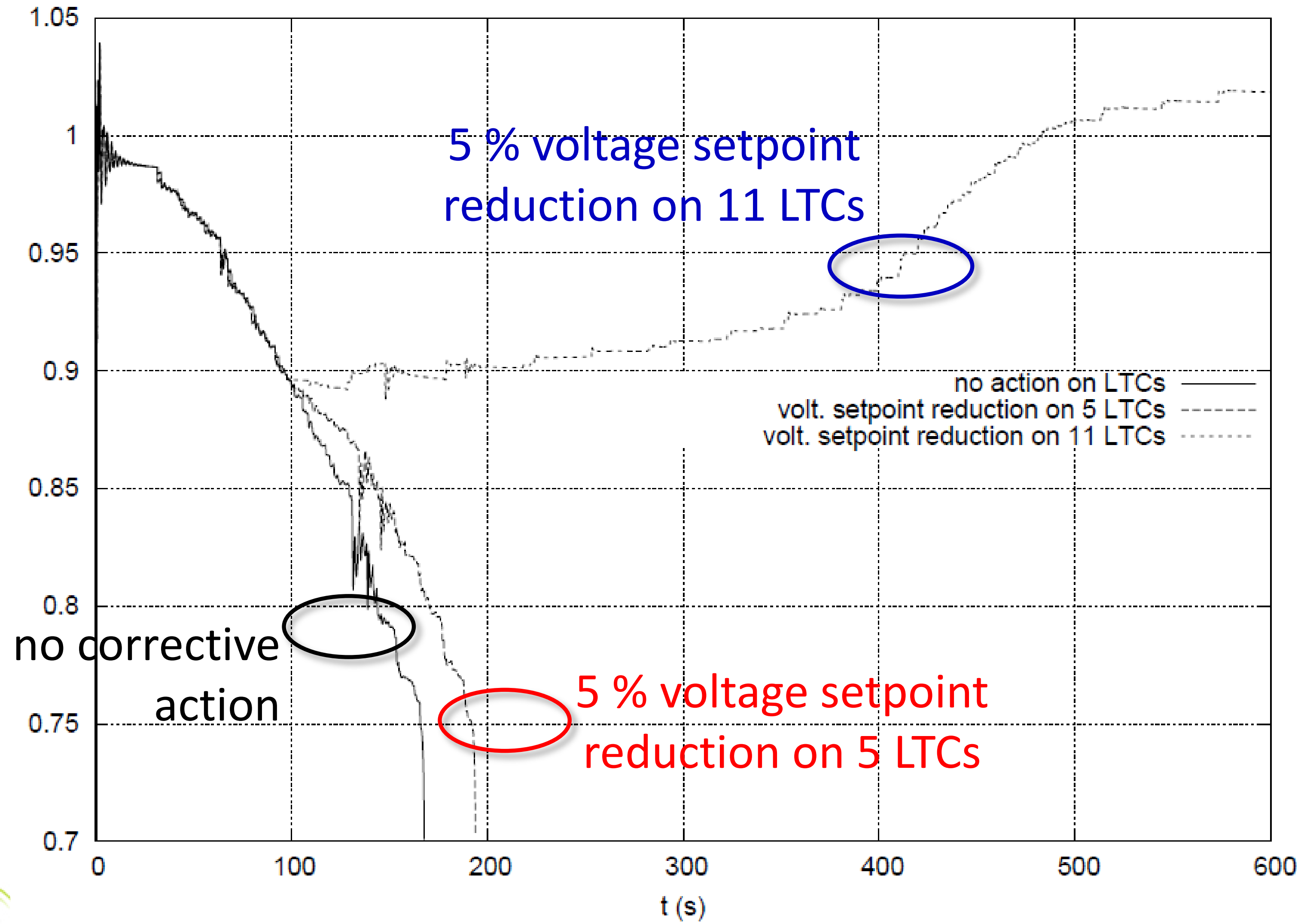
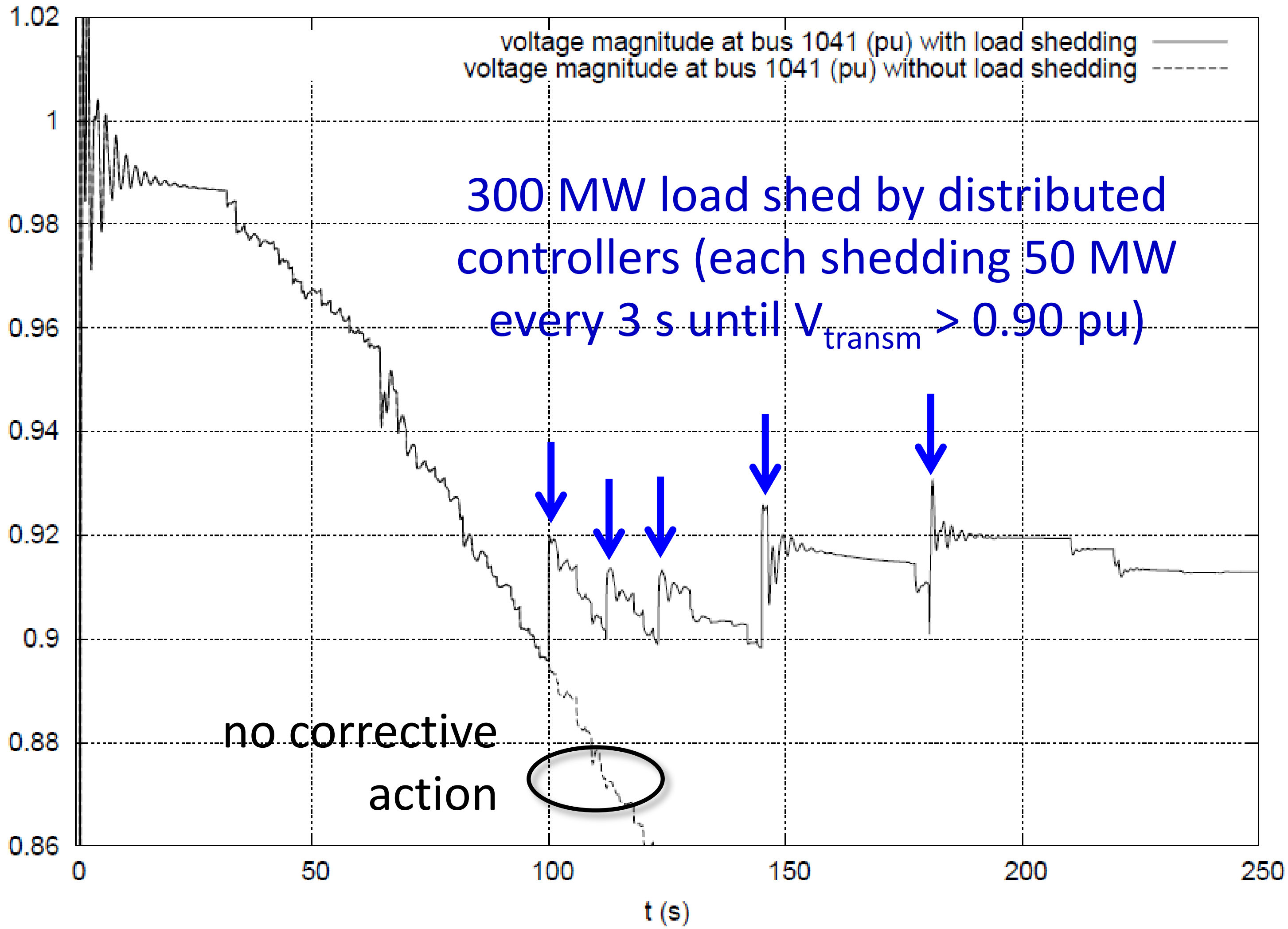
Corrective control : LTC voltage set-point reduction



Corrective control : undervoltage load shedding



Concluding remarks

- A truly voltage stability limited system
  - post-disturbance critical voltage $\sim$ 0.92 pu at some transmission buses in the example shown
- Can be easily extended to other models and components:
  - new IEEE OEL models
  - induction motor loads (→ short-term voltage stability)
  - HVDC links
  - effect of generation connected at distribution level
  - etc.
- Its use should be encouraged in research and in publications

Thank you for your attention !

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