THE NORDIC TEST SYSTEM FOR VOLTAGE STABILITY ASSESSMENT

Thierry Van Cutsem

Department of Electrical and Computer Engineering
University of Liège, Belgium

Université de Liège

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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 the so-called “Nordic32” system proposed in 1995 by a CIGRE WG

• focus 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
Hydro units - primary frequency control

Long, series-compensated 400-kV lines

Thermal units - constant mechanical power

Synchronous condenser
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 below 0.85 pu (except during faults)
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Exciter, AVR, PSS and OverExcitation Limiter (OEL)

fixed delay or inverse-time
Capability curves of round-rotor generators for various terminal voltages
Turbine model

Speed-governor model
Load model

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

\[ P = P_0 \left( \frac{V}{V_o} \right)^{\alpha} \]
\[ Q = Q_0 \left( \frac{V}{V_o} \right)^{\beta} \]
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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

LTC tap changes
Secure oper. point B - Voltage at LTC-controlled distrib. buses
Insecure oper. point A - Transmission voltages

North area

South area

Central area

bus 1041 : voltage magnitude (pu)
bus 1042 : voltage magnitude (pu)
bus 4012 : voltage magnitude (pu)
bus 4062 : voltage magnitude (pu)
Insecure oper. point A - Generator field currents
Insecure op. point A - Voltage at LTC-controlled distrib. bus

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

g6 going out of step wrt other generators
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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 the Central area load
  • long-term dynamic simulations to assess the system response to each contingency
Example of SOL determination - secure oper. pt B

- marginally stable case
- marginally unstable case

at operating point B
- oper. pt B with central load increased by 350 MW
- oper. pt B with central load increased by 375 MW
- oper. pt B with central load increased by 400 MW
- oper. pt B with central load increased by 500 MW
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Corrective control: LTC voltage set-point reduction

- 5% voltage setpoint reduction on 11 LTCs
- No corrective action
- 5% voltage setpoint reduction on 5 LTCs
Corrective control: undervoltage load shedding

300 MW load shed by distributed controllers (each shedding 50 MW every 3 s until $V_{transm} > 0.90 \text{ pu}$)

no corrective action
Thank you for your attention!

t.vancutsem@ulg.ac.be
www.montefiore.ulg.ac.be/~vct
Insecure oper. point A - Generator terminal voltages