Active Distribution Network (ADINE) Modeling and real-time simulation

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Contents

• Real-time digital simulations with RTDS
• Combination of RTDS and dSPACE simulations
• Example of “ideal” simulation sequence
• Interaction simulation
Hardware in loop testing

PC workstation

DOPTO Card

RTDS®

D/A Cards

Network model

HV/MV Transformer 110kV/21kV

CB_Feeder

PL

Node 1

PL

Node 2

PL

Node 3

PL

Node 4

CB_100

DG unit: Synchronous machine 1.6MVA

Y

Y

21kV/0.66kV

Control signals

Feeder relay & LOM Relay

Current- & voltage measurements

Amplifier

Amplified signals

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Non-detection zone of LOM

1.6 MVA hydro power unit, Synchronous generator
Exciter + AVR (IEEE AC8B) and Q controller (IEEE Var Type 2)
No turbine or governor controller
Non-detection zone of LOM

Frequency and voltage functions

Frequency and voltage Functions + ROCOF

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Combination of RTDS and dSPACE

dSPACE is real-time simulator for control systems
(we use dSPACE to model power electronics and its control)
Full power converter models
Example of full power converter FRT simulations

Fig. 4.4. a) Connection point voltage, b) Connection point current.

Fig. 4.5. a) d-component of the grid current and its reference, b) dc-link voltage and chopper current during the fault.

Fig. 4.6. a) Instantaneous active power of the generator and its reference, b) Connection point instantaneous reactive power and its reference.

Fig. 4.7. a) q-component of the NSC current and its reference. b) Electrical torque of the generator.

Fig. 4.8. a) Rotational speed of the turbine and its reference, b) Instantaneous active power in

Output power reduction

Pitch control activated

Kinetic energy increases

Reactive power support

Reducing electrical torque

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Microturbine LV network simulations

Network → Load → Sensitive load

3 Phase Motor start

3% Tap change in MV net

Dip on the HV net giving remaining V of 90% for 0.3 s

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Co-ordinated voltage control

Matlab
  State estimation
  Coordinated voltage control

OPC: Measurements
  Commands
  Operator

SCADA → DMS

Setting values

110 / 20 kV substation

AVR

Hydro power plant

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Loadflow studies

Voltage at wind farm connection point

Wind power production

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Benefits of co-ordination

- Unity power factor, Flexible
- Local voltage control, Flexible
- Co-ordinated control, Flexible
- Unity power factor, Fixed
- Local voltage control, Fixed
- Co-ordinated control, Fixed
Time domain performance in PSCAD

- 4 units are connected: Tm 0.0 → 0.5 pu
- 2 units are disconnected
- 2 units are disconnected

- Voltage limits of Basic control
- Voltage limits of Restoring control
- Voltage setting of OLTC
- Substation voltage

- The voltages are restored to an acceptable level
- Basic control decreases OLTC setting value
- Delay of basic control
- Delay of AVR and tap changer
- Tap changer operates

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RTDS testing of control algorithm

Network simulation

RTDS

RTDS workstation

RSCAD

MATLAB

SCADA

OPC

OPC

shared files

Network voltages are restored to an acceptable level

Tap changer operates

Network voltages are restored to an acceptable level

Maximum voltage

Minimum voltage

Generator voltage

Substation voltage

Voltage set point of OLTC

Voltage limits of basic control

Voltage limits of restoring control

AVC relay deadband

Basic control decreases AVC set point

Restoring control increases AVC set point

State estimation

Co-ordinated voltage control

0.95
1.0
1.05
1.1 [pu]

Voltage set point of OLTC
Interactions of STATCOM and DFIG wind turbine

**Fig. 3.8. WTPCC voltage:**
- a) without statcom
- b) with statcom

**Fig. 3.9.**
- a) Statcom reactive power
- b) Statcom phase currents
Fig. 3.10. Real power of DFIG: a) without statcom, b) with statcom.

Fig. 3.11. Reactive power of DFIG: a) without statcom, b) with statcom.
**Fig. 3.12. DFIG rotor current:** a) without statcom, b) with statcom.

**Fig. 3.13. dc-link voltage of the frequency converter:** a) without statcom, b) with statcom.
Test sites

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Thank you!

www.adine.fi