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Grid-off LV distribution network with biogas station

– analysis of voltage and frequency variation

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Introduction

Grid-off power system

- a part of the distribution system operated autonomously as a separate unit to meet the territory's need of supply with a proper voltage quality.
- can be operated in remote or sparsely populated areas that are far from the grid.
- usage of electricity generated from local sources can be cheaper than building a new distribution feeder or reconstruction of existing one.
- dynamic unbalance between power demand and supply causes stronger variations in frequency and voltage compared with grid-connected mode.

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Case study

- submitted by a undisclosed distributor.
- to investigate voltage and frequency changes caused by load fluctuation in an autonomous LV network located in rural area.
- grid-off system is supplied by a local source in continuous operation (e.g. biogas station) and the photovoltaic power plant.
- voltage and frequency variations are caused by switching of common household equipment (electric cookers, consumer electronics, heaters, lights…), electric boilers and circular sawing machine

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Case study

- Voltage and frequency variations caused by common household equipment switching are evaluated in compliance with the standard EN 50160.
- Under normal operating conditions the mean value of the fundamental frequency measured over 10 seconds shall be within a range of 50 Hz ± 2% during 95% of time, and within the range 50 Hz ± 15% during 100% of time for systems in island mode
- During stabilised operation of the network, 95% of rms voltage values measured over 10 min shall be within the range 400 V ±10% during each period of one week, and within the range 400 V +10/-15% during 100% of time.

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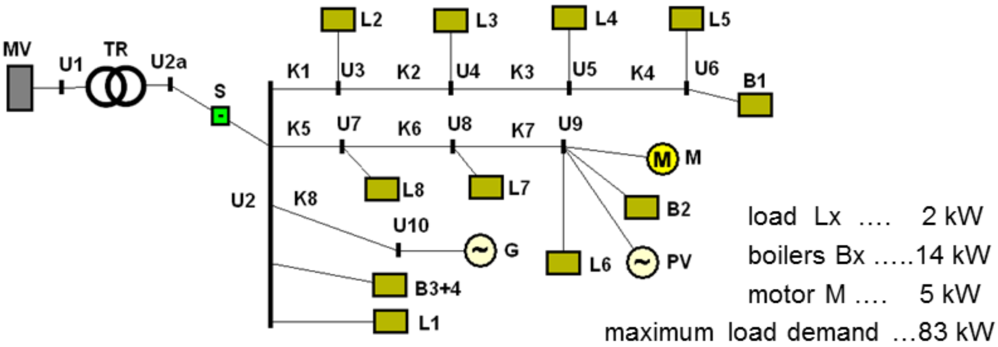
Description of the 0,4 kV network

- network is supplied by stand-alone 95 kW synchronous generator or with assistance of 10 kW PV plant.
- network consists of overhead lines



- in grid-connected mode, source impedance in U6 and U9 is just equal to the EMC reference impedance

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Load states under consideration

- to obtain the worst voltage conditions all single-phase equipment are connected to the same phase
  - → higher voltage unbalance and changes in given phase
    (single-phase equipment causes voltage drop on both phase and neutral conductor)
  - → higher demands on the generator control system
    (driving-machine power regulator, respectively on generator excitation control)
- load states
  - State 1: equipment 12 kW
  - State 2: equipment 12 kW + motor 5 kW
  - State 3: equipment 22 kW + motor 5 kW + boilers 56 kW

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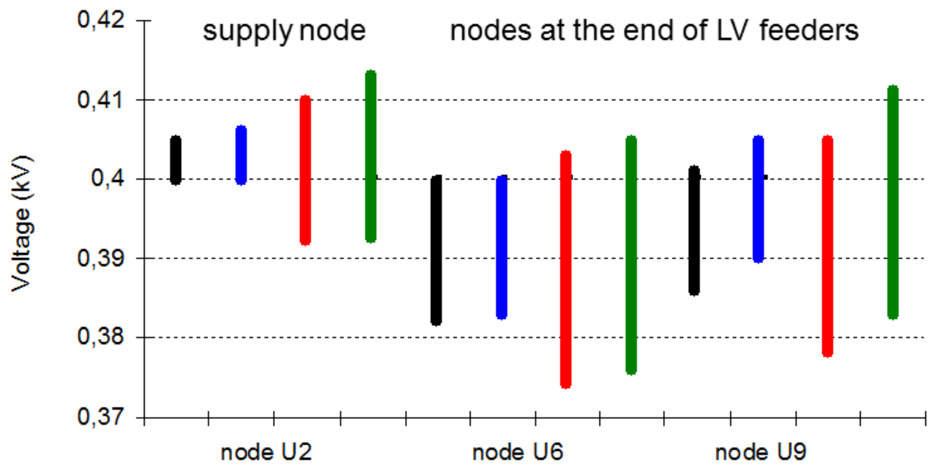
Voltage range for minimal and maximal demand



grid-connected mode with G
grid-connected mode with G+PV
grid-off mode with G
grid-off mode with G+PV

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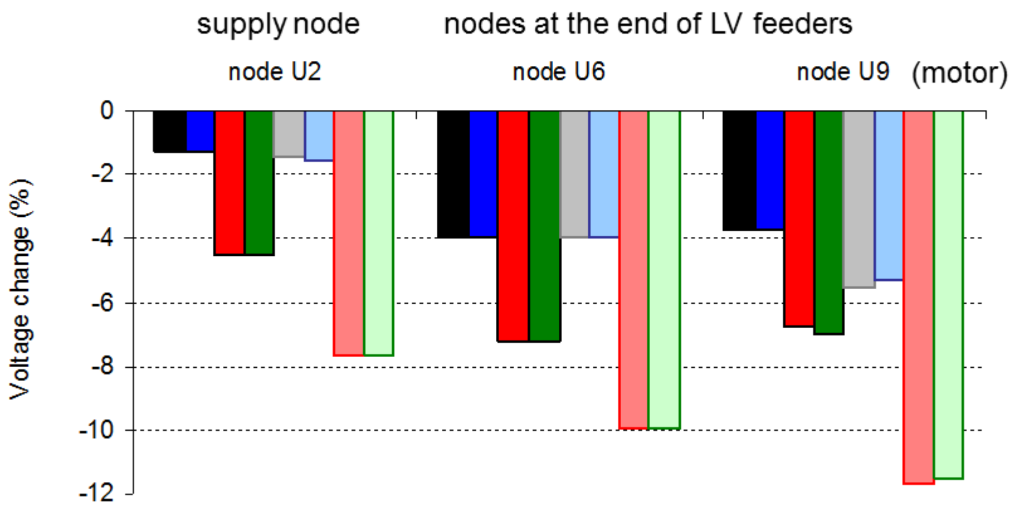
Voltage changes caused by load change (1→3)



grid-connected mode with G
grid-connected mode with G+PV
grid-off mode with G
grid-off mode with G+PV

dark columns … in steady state

lighter columns … during motor starting

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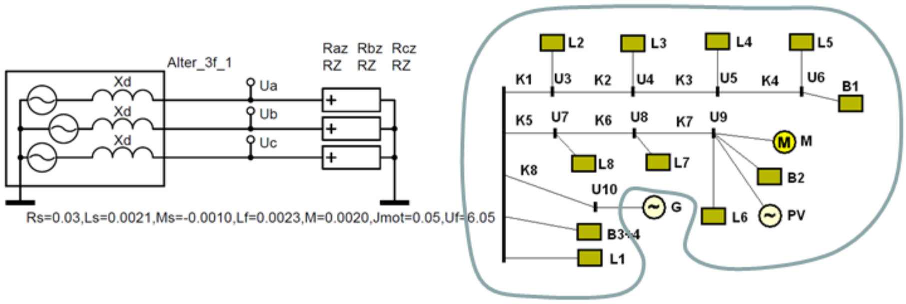
Dynamic angular stability during sudden load changes

- analysed in the Dynast tool
- is considered the extreme load unbalance, single-phase equipment is connected to the same phase
  → torque oscillations, alternator active power fluctuations



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Dynamic angular stability during sudden load changes

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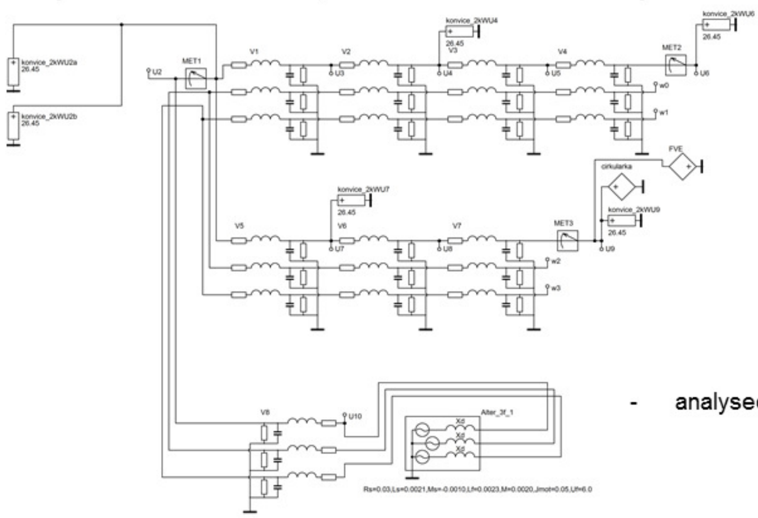

- analysed in the Dynast tool

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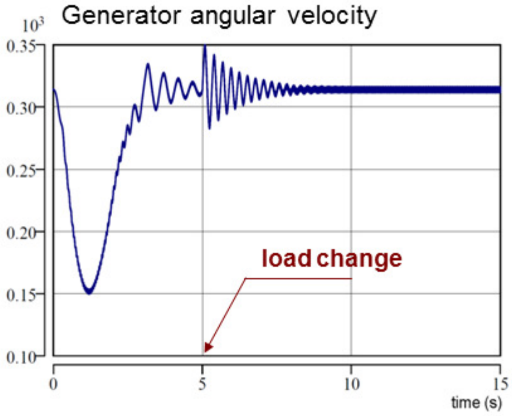
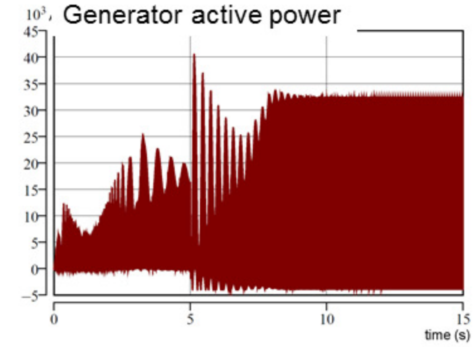
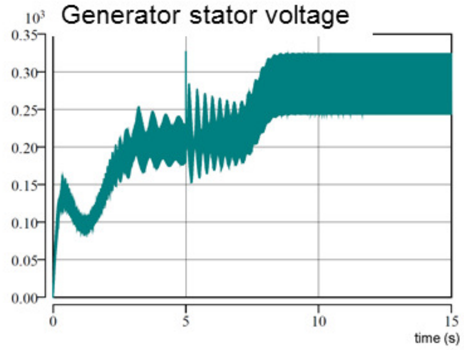
Dynamic angular stability during sudden load change (1→2)

- minimal load + motor starting

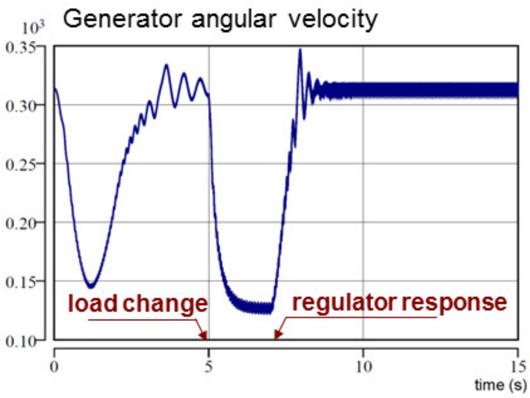


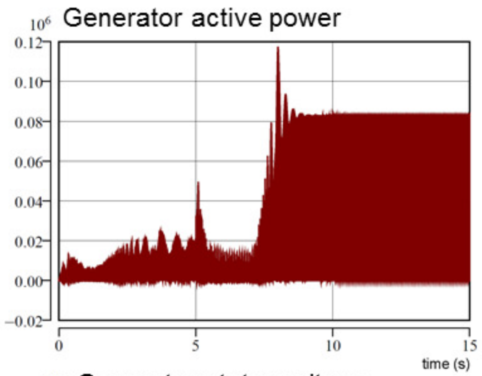


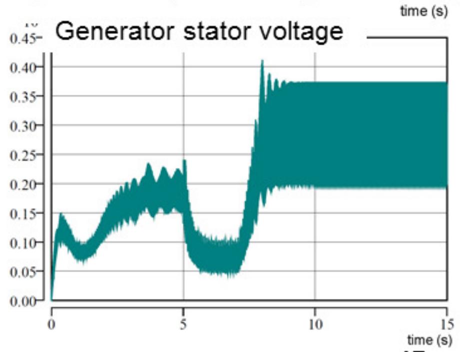


Dynamic angular stability during sudden load change (1→3)

- minimal load → maximal load







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Conclusions

- Voltage variations meet the standard EN 50160, although voltage variation range is wider and voltage changes caused by load switching are almost twice as high as those in grid-connected mode.
- Simulations of dynamic performance of grid-off system show that it is possible to expect stable synchronous operation without frequency drop, but some oscillations of all system parameters will occur.
- The case study was intently carried out for extreme load unbalance in the network. In actual operation even better conditions are expected.

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Thank you for your attention.

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