Behavior of a turbocharged gas engine during a low voltage ride through

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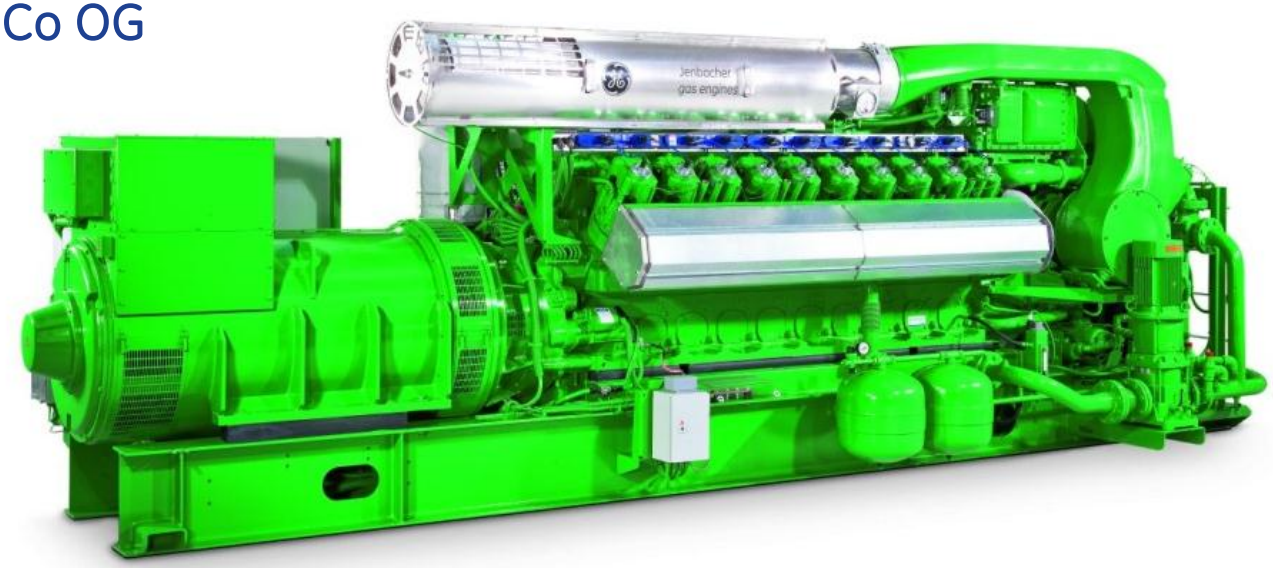

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Content

- Introduction
- Grid code
- Behavior during a low voltage ride through (LVRT)
- Operating strategy during LVRT
- Simulation of engine behavior during LVRT
- Validation of GE's Jenbacher gas engines portfolio
- Summary

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Introduction

- Change in electrical power production
- More small decentralized power producers

  ➔ Higher danger for reduced grid stability

- Until now disconnection of the decentralized power producer from grid during voltage drop

  ➔ Domino effect

  ➔ Network breakdown

  ➔ Blackout

- Since beginning of the year 2013 there was the introduction of new rules in Europe for power producers

  ➔ **No** disconnection from the electrical grid during a voltage drop (low voltage ride through)

  ➔ Electrical grid stays stable while this voltage drop

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Grid-Code

- Grid code is the rule to supply electrical power to the grid
- Static grid stabilization: request to stabilize the electrical grid (power level, voltage, frequency, power factor)
- Dynamic grid stabilization: behavior of power producer during a low voltage ride through

  Request Germany:

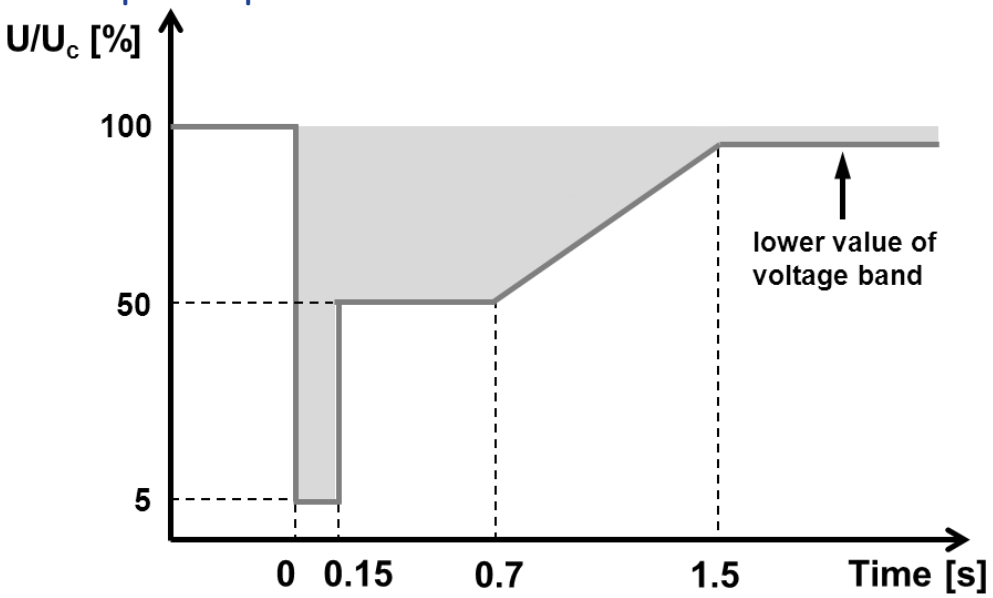
  – Voltage drop with a duration of max. **t = 150ms** and down to max. **U = 30% without disconnection from grid**

  – Second voltage drop within 0.3 s until 2 s possible **without disconnection**

  – 5s after voltage drop min. 95% of power output required

  Request France:

  – Voltage drop during **t = 150ms** and voltage **U = 5% without disconnection from grid**



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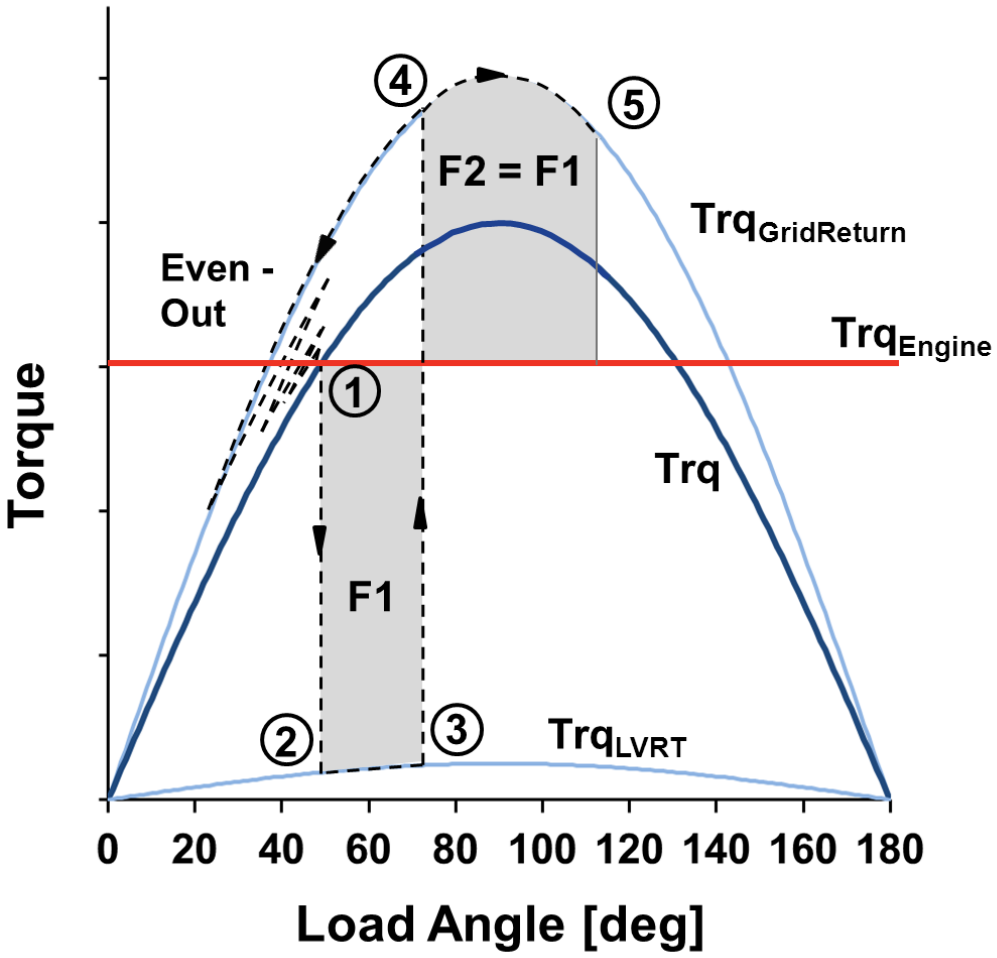
Behavior during a low voltage ride through (LVRT)



Synchronous generator:

- Stable operating point **(No. 1)**
- Immediate reduction of generator torque at the voltage drop **(No. 2)**
- Engine accelerates ➔ load angle increases **(No. 3)**
- After voltage drop for a short time a higher generator torque **(No. 4)**
- The load angle increases caused by the area criteria (F2 = F1) **(No. 5)**
- Operating point tries to reached stable conditions with oscillating changes **(No. 1)**

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Behavior during a low voltage ride through (LVRT)

Increasing change of load angle causes increased:

Mechanical load of :

- Generator
- Engine
- Coupling between engine and generator

Tipping movement of the engine caused by the generator torque:

- Too great radial movement of the compensators
- Danger of cooling water and oil leakage

Goal: Minimizing the load angle change during a low voltage ride through

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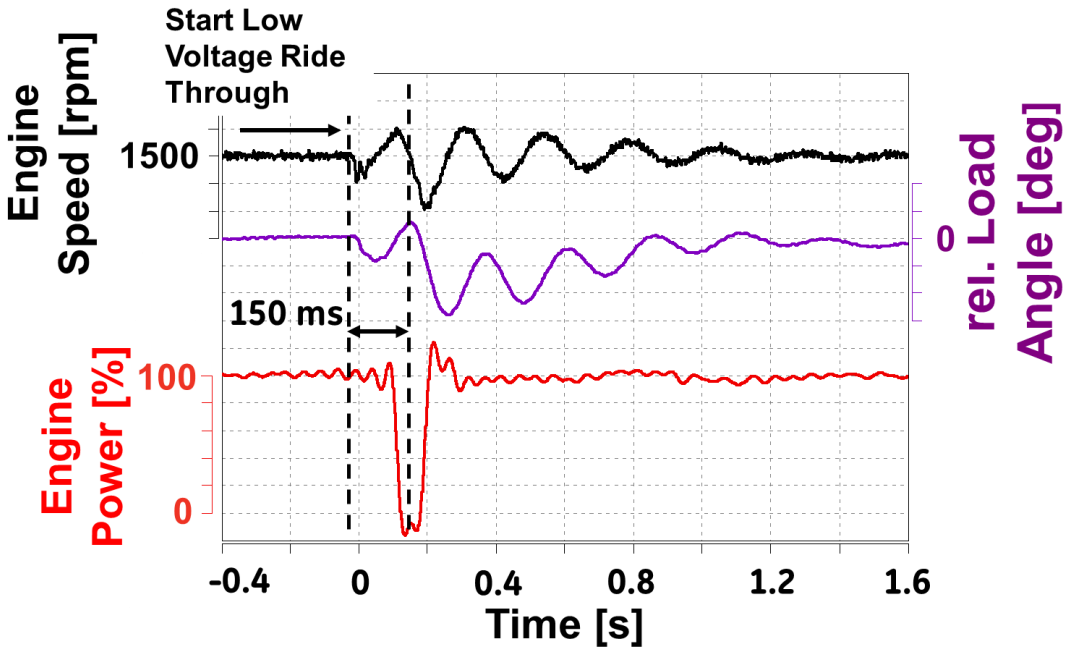
Operating strategy during LVRT

Controlled short deactivation of the ignition system during a low voltage ride through

➔ Active influence on engine acceleration

➔ Goal: Keep load angle within predefined threshold values



- Engine control system detects a LVRT
- Ignition OFF, when the load angle is greater than the threshold value
- Engine acceleration will be stopped
- Ignition ON, when the load angle is below threshold value

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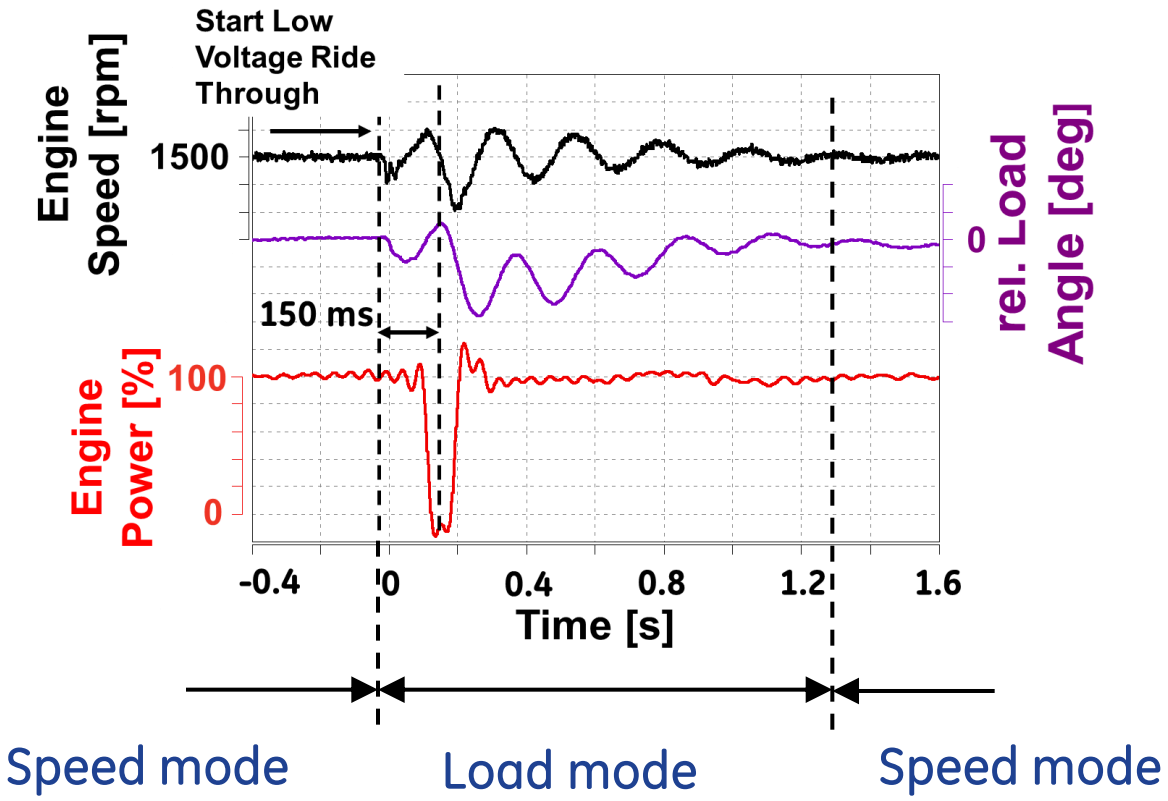
Simulation of engine behavior during LVRT

- Speed and load mode



➔ Change of mode not possible within simulation

➔ Use of measured speed or calculation in another tool

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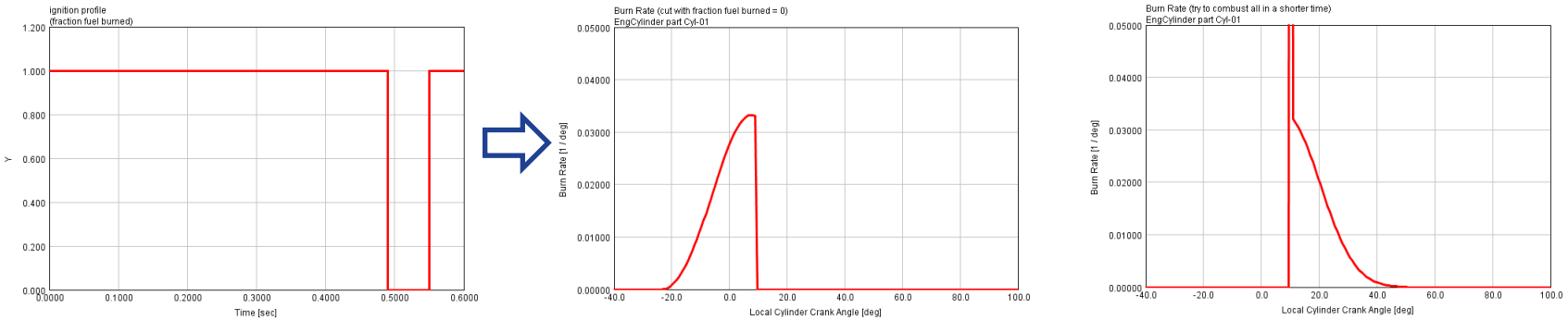
Simulation of engine behavior during LVRT

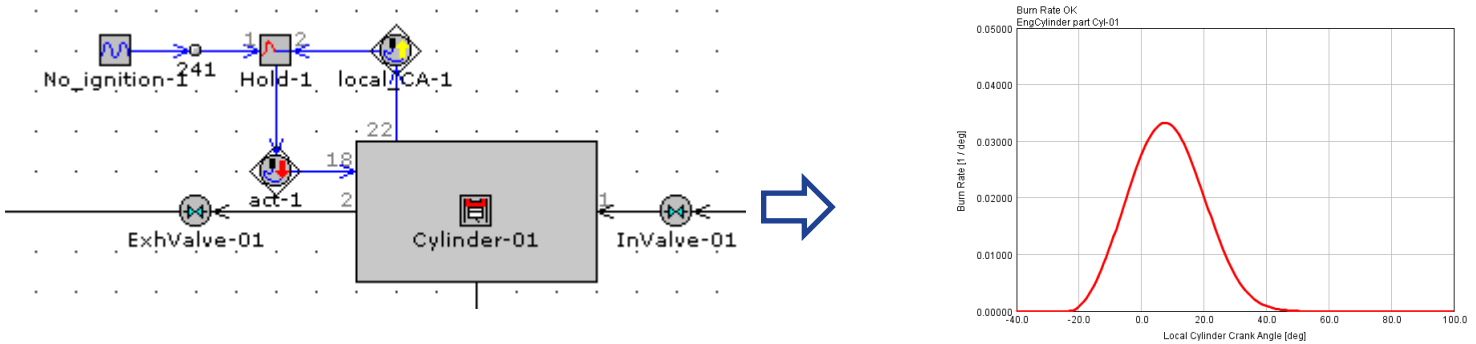
Simulation of ignition off:

1. Approach: time dependend table for fuel fraction burned (combustion)



➔ Combustion starts or ends within combustion profile (when the value changes to 1 or 0)

2. Approach: signal hold function to prevent change within the profile



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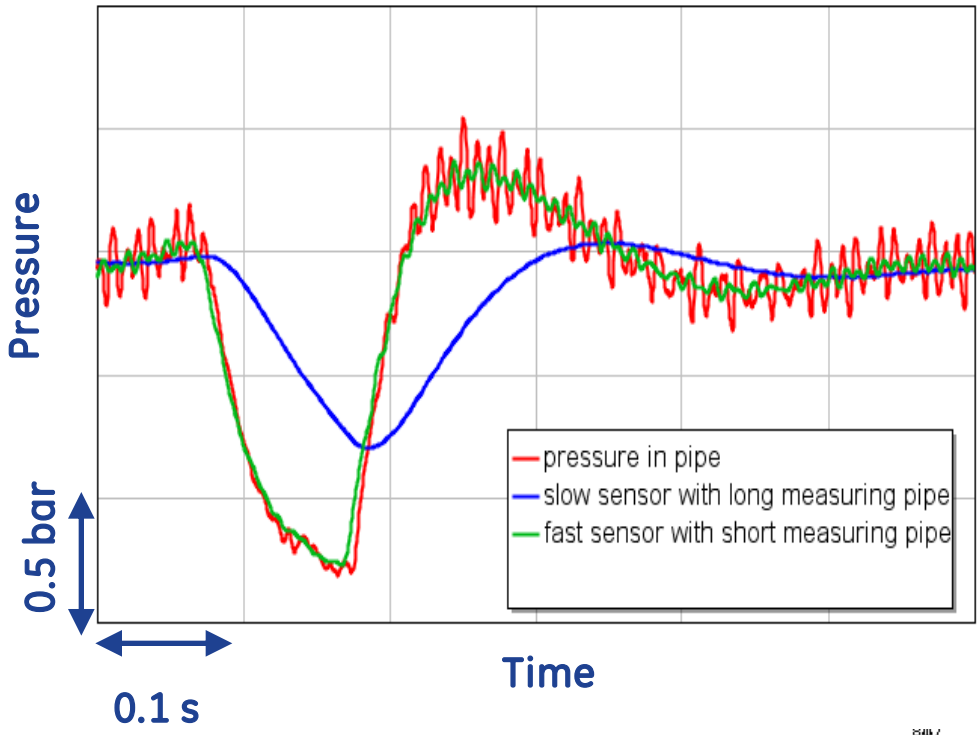
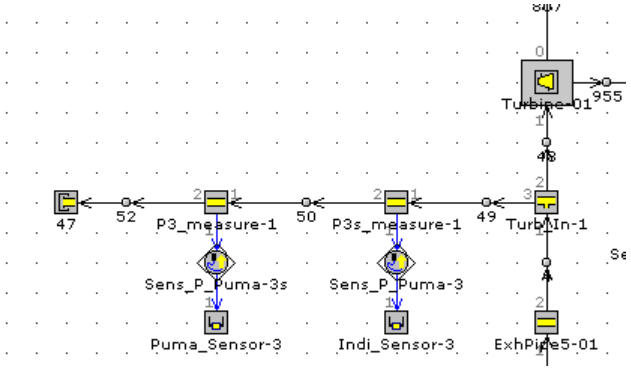
Simulation of engine behavior during LVRT

Pressure sensor (response time and measuring pipe)



- Standard pressure sensor too slow and measuring pipe too long
- Faster pressure sensor and no (or short) pipe is nearly perfect



- Sensor response time with template FirstOrderFilter

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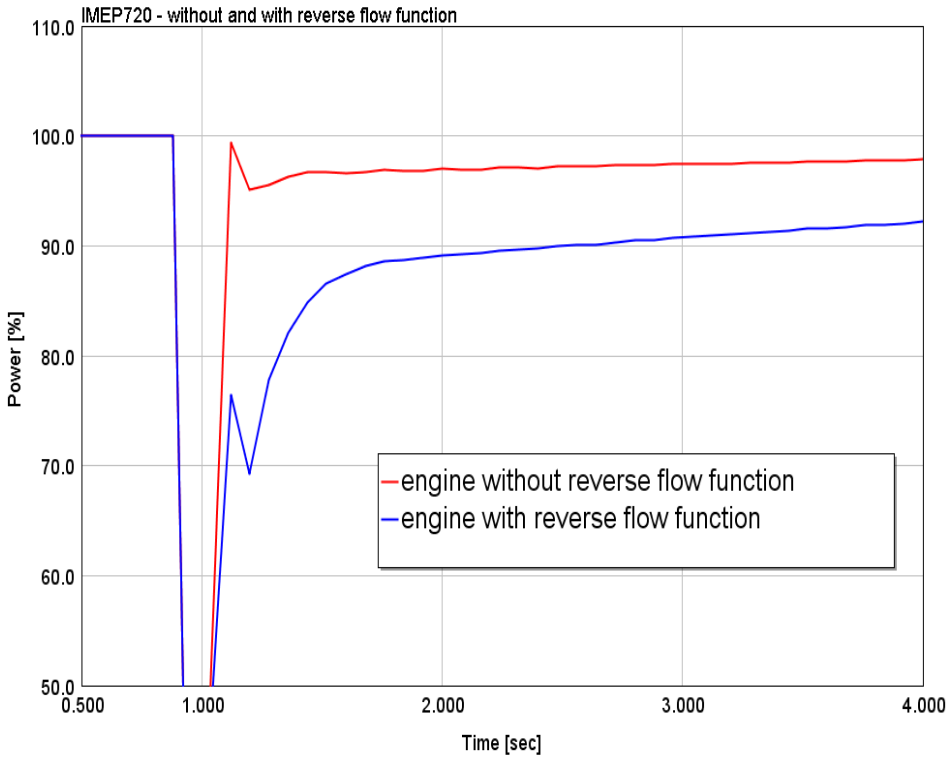
Simulation of engine behavior during LVRT

Compressor model without and with reverse flow function



When compressor stalling occurs (caused by ignition off):

- Nearly no power drop without reverse flow function
- Very high power drop with reverse flow function

➔ If stalling occurs, then the reverse flow function is necessary

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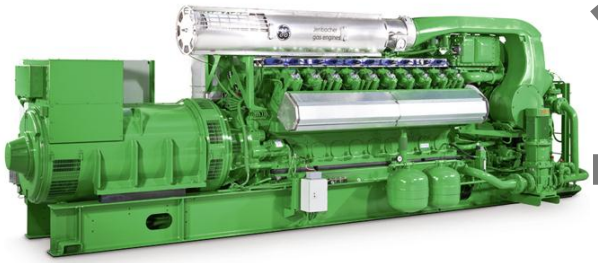
Validation of GE's Jenbacher gas engines portfolio

High number of variants within one engine type:

Inter cooler temperature

Cylinder number

- GenSet version
- CHP version



Min. Methane number
- MZ 70
- MZ 80

Generators

NOx emissions:
- 500 mg/Nm³
- 250 mg/Nm³

Different turbocharger configurations

➔ Number of variants is too high to test every engine on the test bench

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Validation of GE's Jenbacher gas engines portfolio

Prediction of compressor stalling and BMEP after LVRT with GT-Power:

- Measurement on the test bench
  - Stepwise increase of the ignition off time …
  - … until compressor stalling occurs
- Simulation of measurement with GT-Power
  - Engine model with correct geometrical dimensions
  - Maps of compressor and turbine
  - Correct rotatory mass inertia of the turbocharger
  - Same ignition off time as measured
  - Engine speed from measurement

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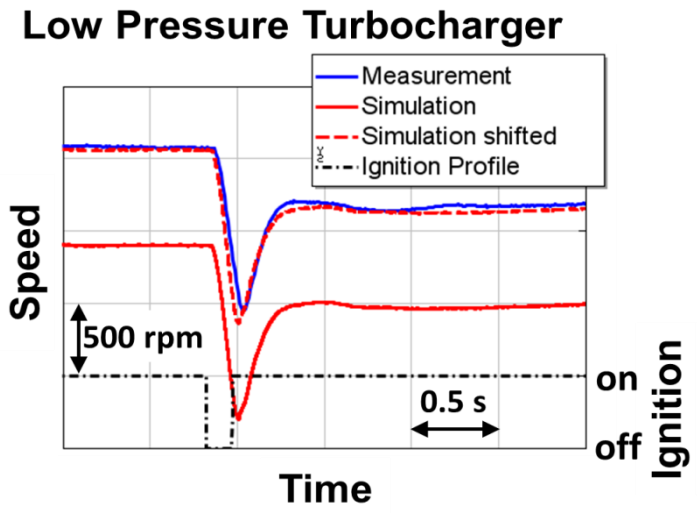
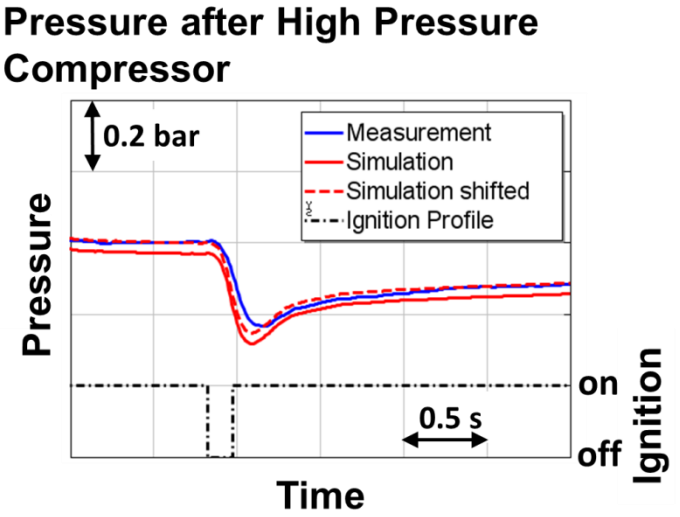
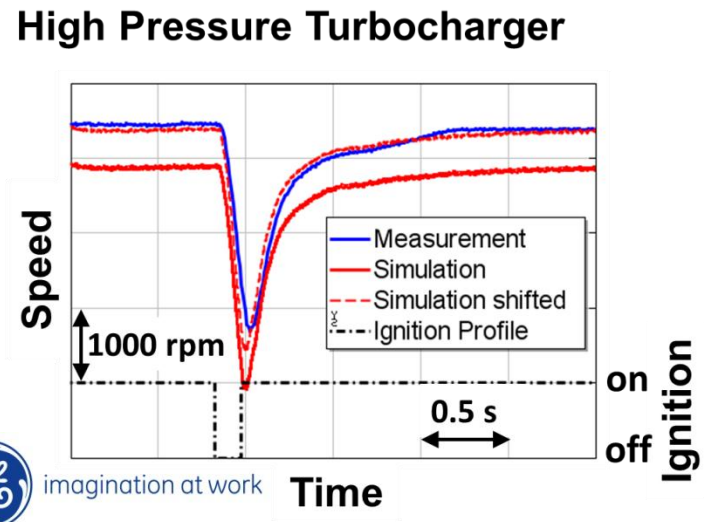
Validation of GE's Jenbacher gas engines portfolio

Comparison of measurement and simulation with GT-Power:

Example: J624 two-stage; time ignition off without compressor stalling







Very good matching for:

- Turbocharger speed
- Pressure behind HP compressor

➔ Correct simulation of very dynamic behavior with GT-Power possible

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Validation of GE's Jenbacher gas engines portfolio

- Electrical grid and profile of LVRT
- Data of generator (e.g. reactance)
- Inertia of engine and generator
- Engine torque characteristic
- …

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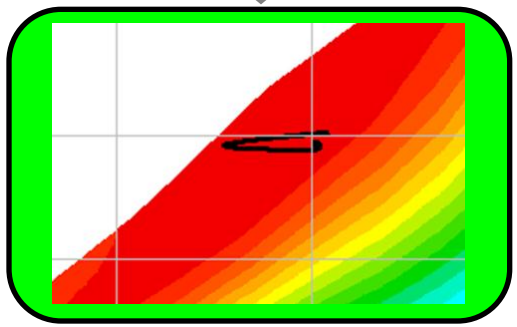
- Ignition profile
- Speed profile

- Engine geometry
- Turbocharger maps
- Operating conditions
- …

GT-Power



- Shift within compressor map
- Power versus time

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Summary

- New rules concerning low voltage ride through (LVRT)
- Operating strategy: Controlled short deactivation of the ignition during LVRT
- Danger of compressor stalling
- Developing of a strategy to predict compressor stalling and power after LVRT with suitable simulation tools
- Verification of all of GE's Jenbacher gas engines with minimized measurement program on the test bench

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Thank you for your attention