Gas Turbine Flexibility and Life Assessment Method

Cranfield UNIVERSITY

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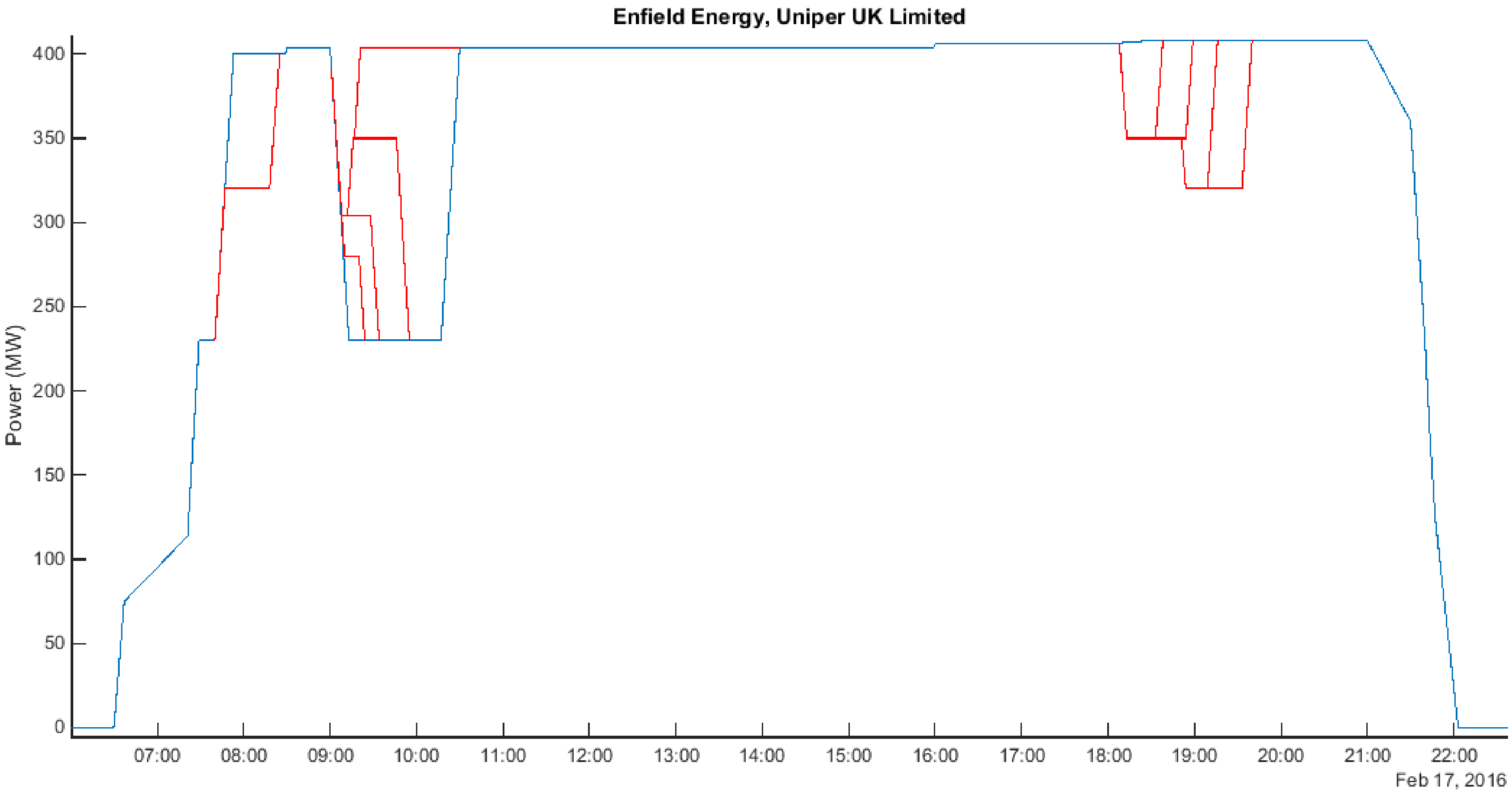
Presentation outline

- Balancing analysis
- Technical background

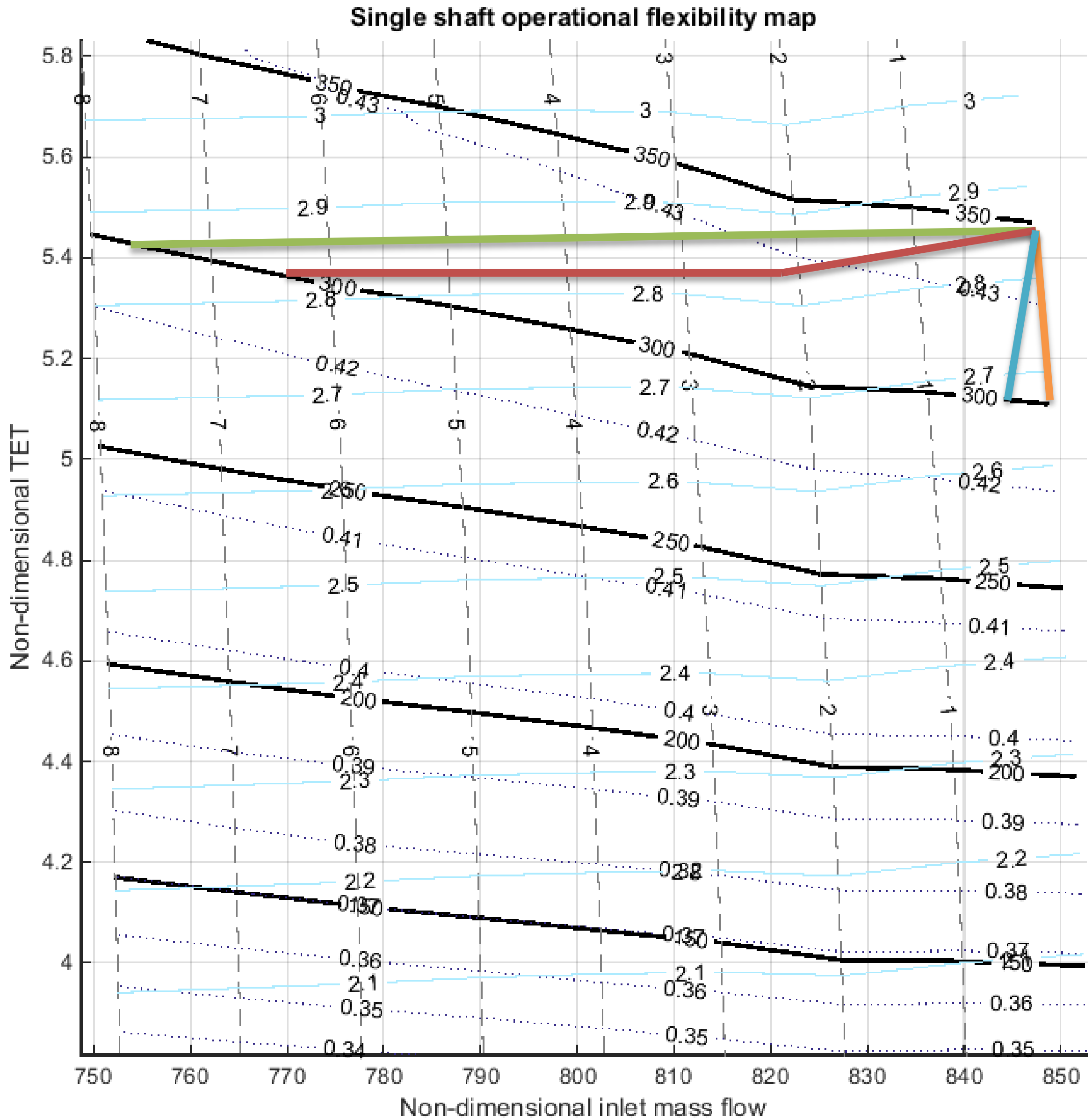
Balancing analysis

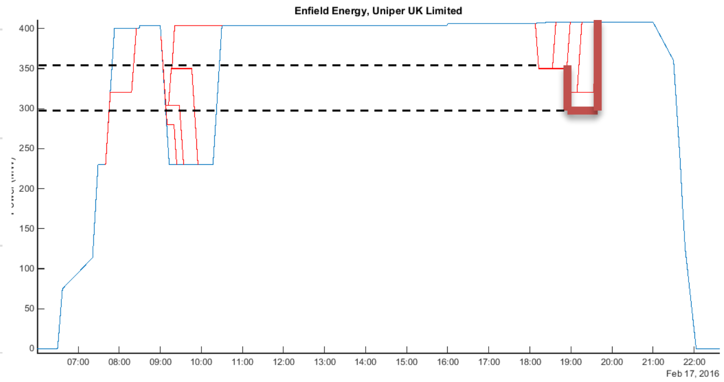
Balancing analysis



Source: bmreports.com

Balancing analysis – operational map





Example:

- 350 – 300 MW

Options to reduce load:

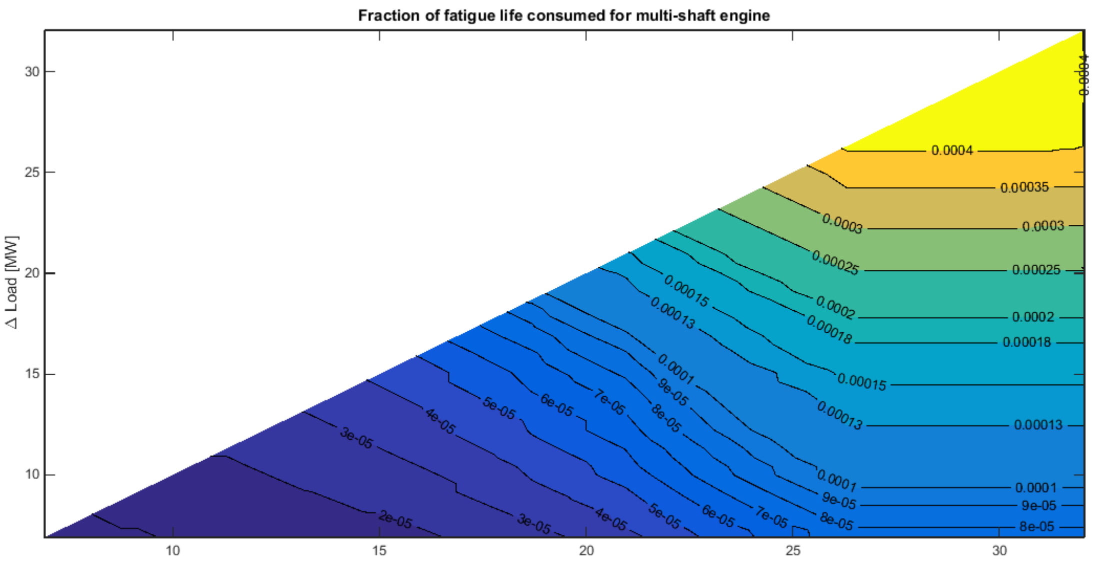
- Constant TET
- Constant Texhaust
- Constant VIGV°
- Custom

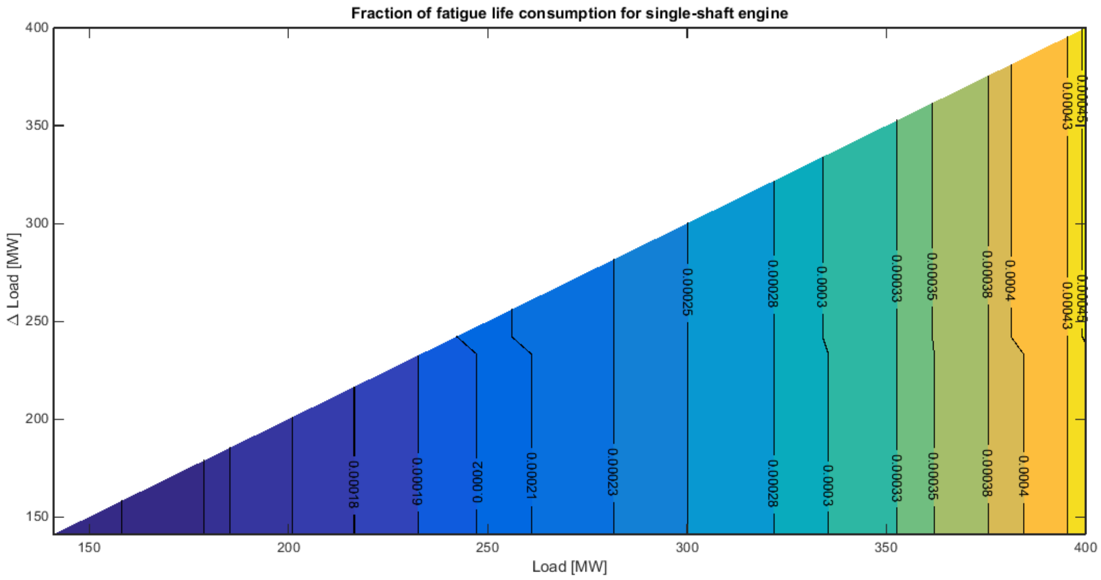
Balancing analysis – operational map

Operational strategy is 

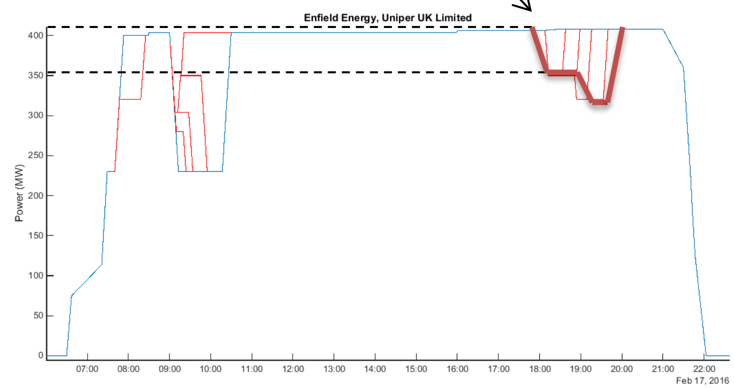
Life analysis ...

Balancing analysis - fatigue





National Grid asks:



Example:

First

- 400 – 350 MW
- Hold for 1 hour

0.045% fatigue consumption

Then

- 350 – 300 MW
- Hold for 1 hour

0.033% fatigue consumption

TOTAL: 0.078%

x 500 times

39% fatigue consumption

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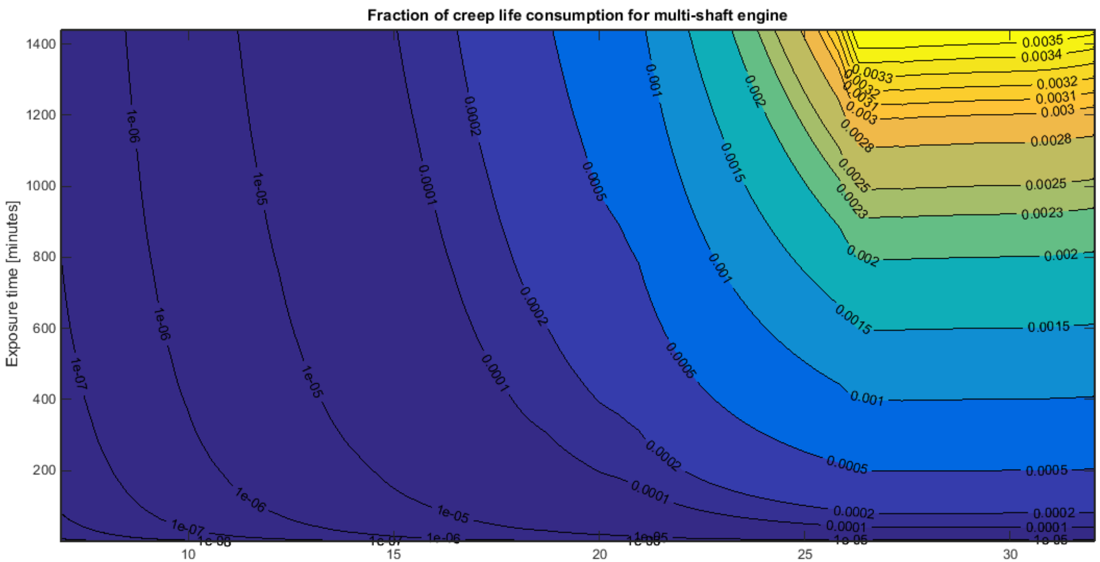
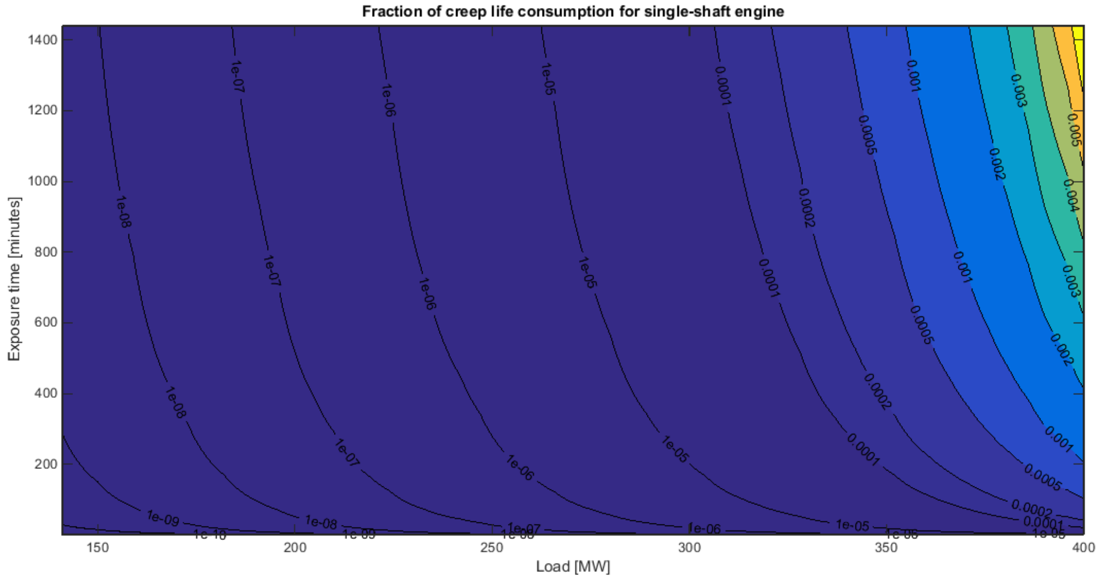
Balancing analysis - creep





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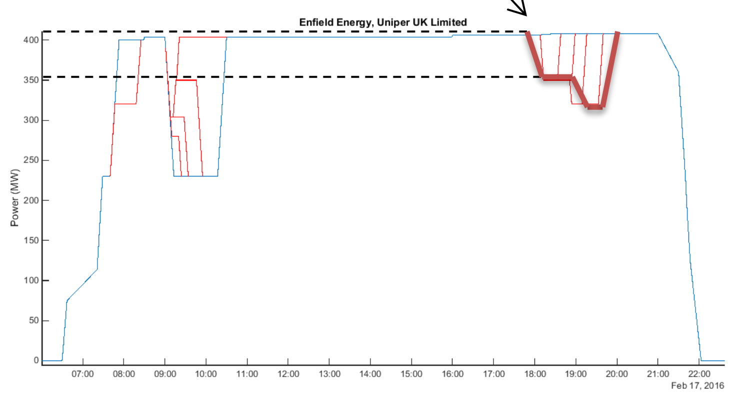


Example:

First

- 400 – 350 MW
- Hold for 1 hour

0.004% creep consumption

Then

- 350 – 300 MW
- Hold for 1 hour

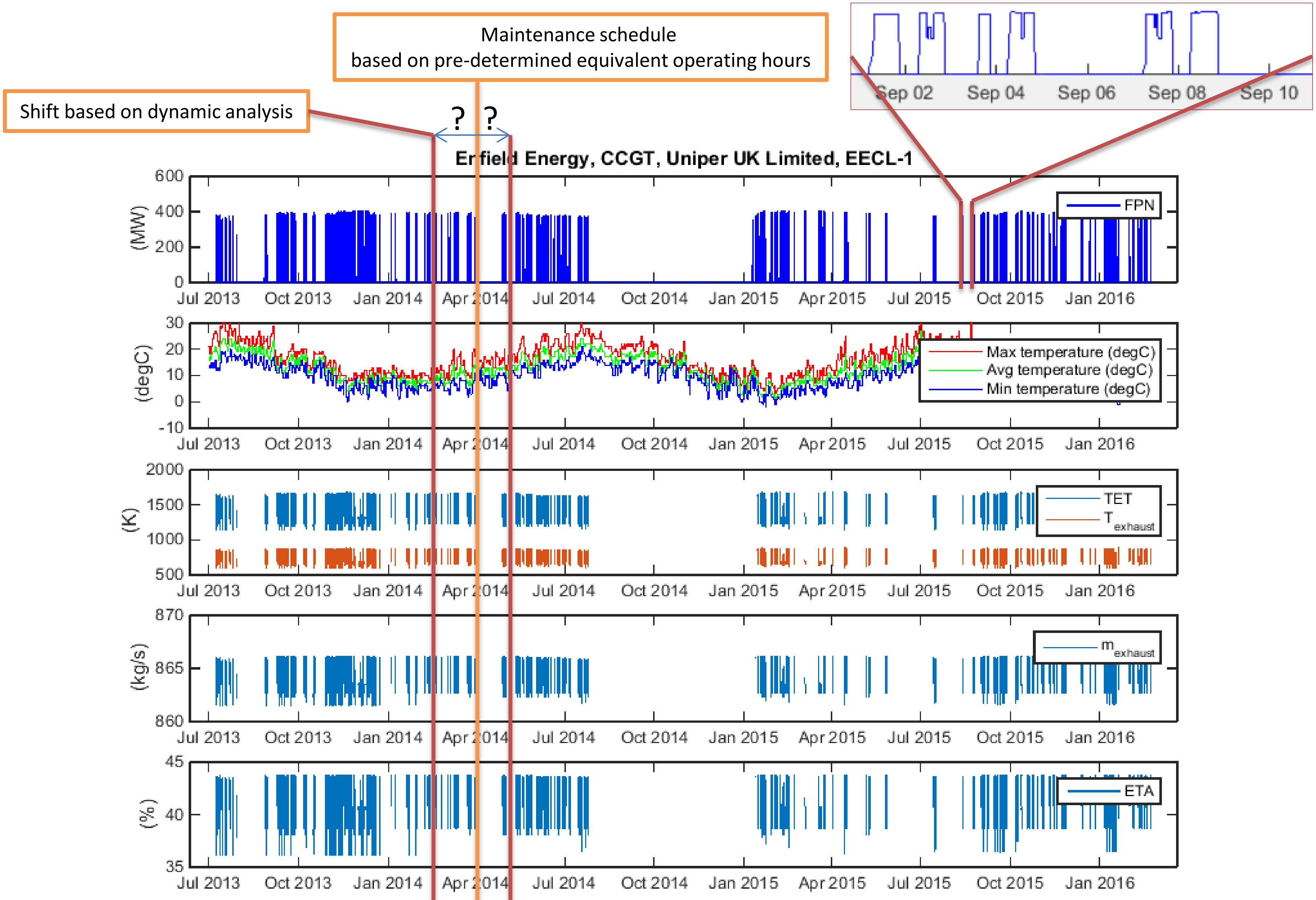
0.0005% creep consumption

TOTAL: 0.00455%

x 500 times

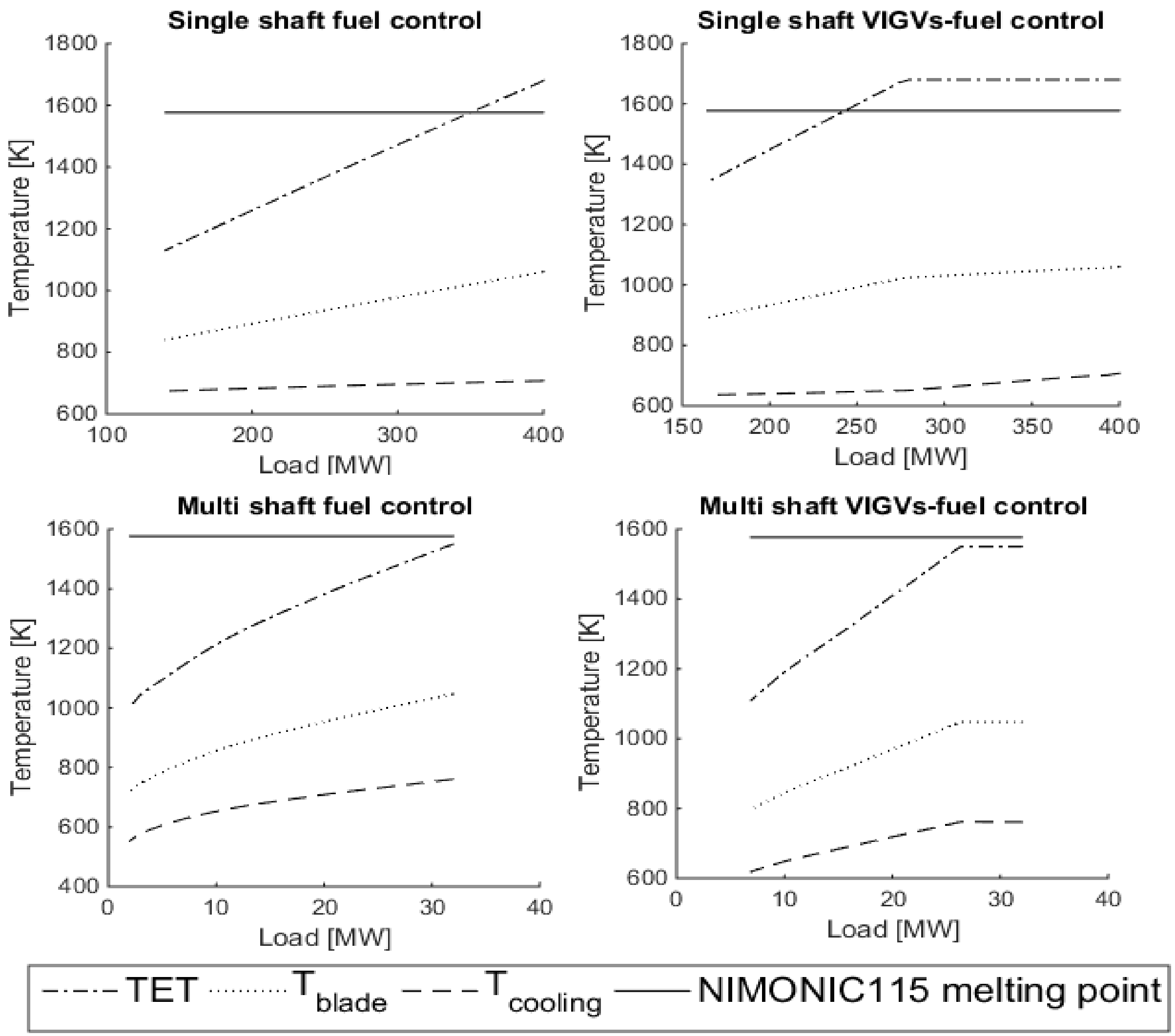
2.3% creep consumption

Global balancing analysis

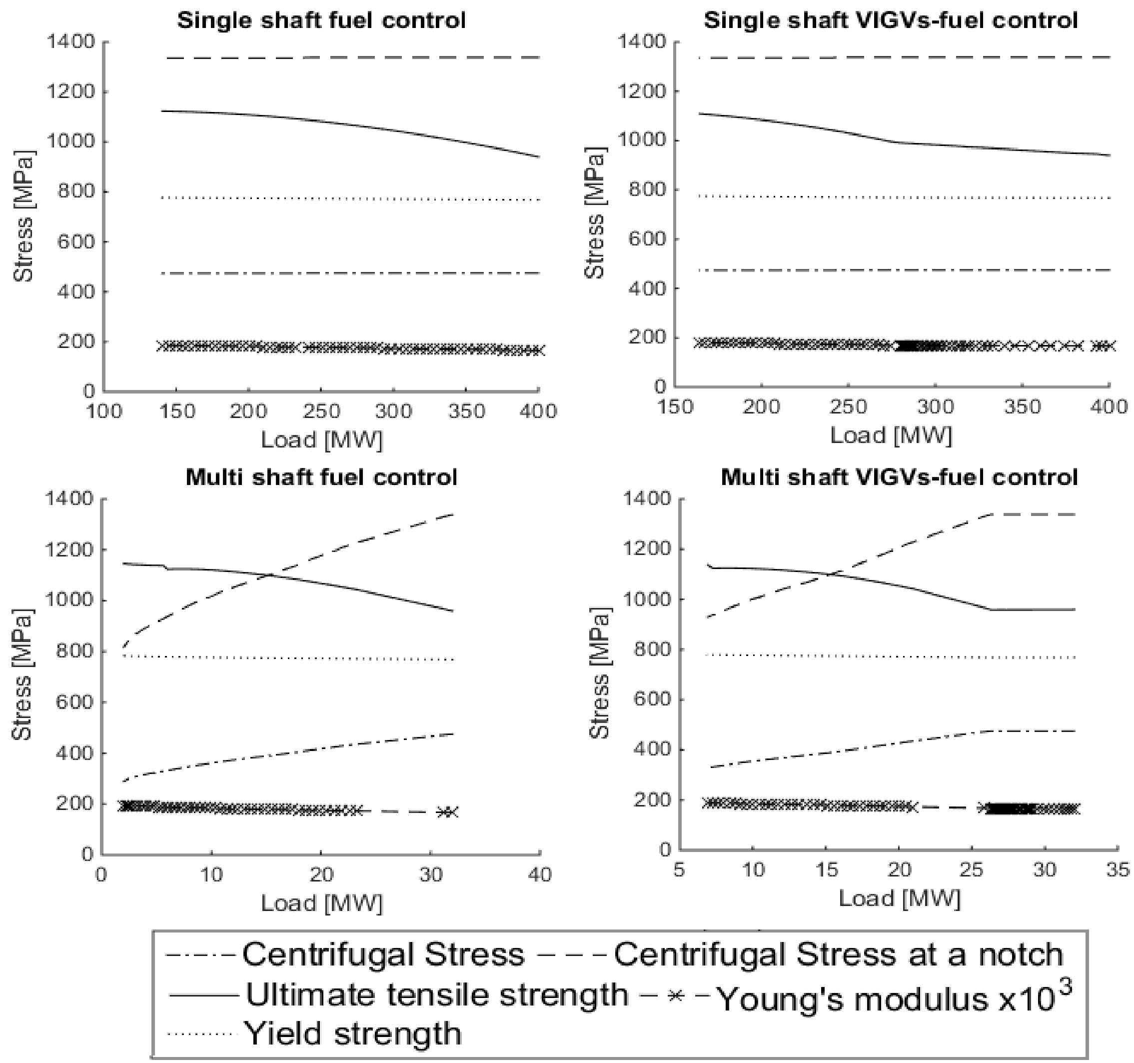


Technical background

Gas turbine performance

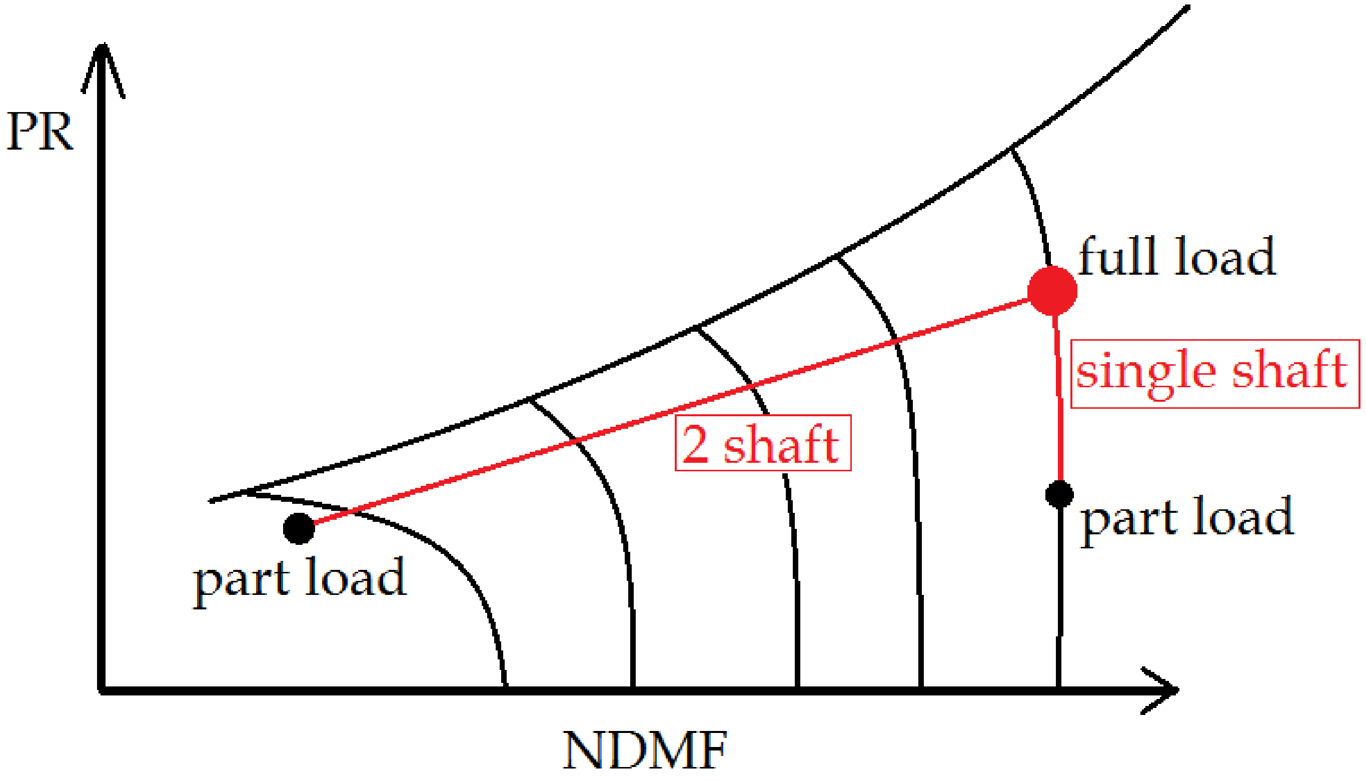


Gas turbine performance



Technical background
– development of operational map

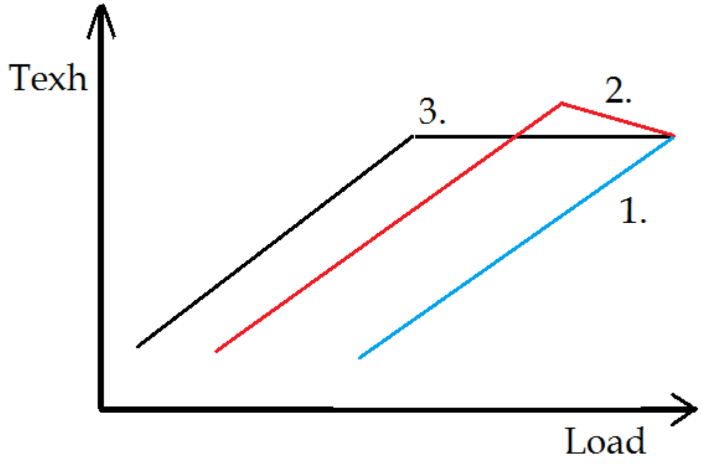
GT Simulation



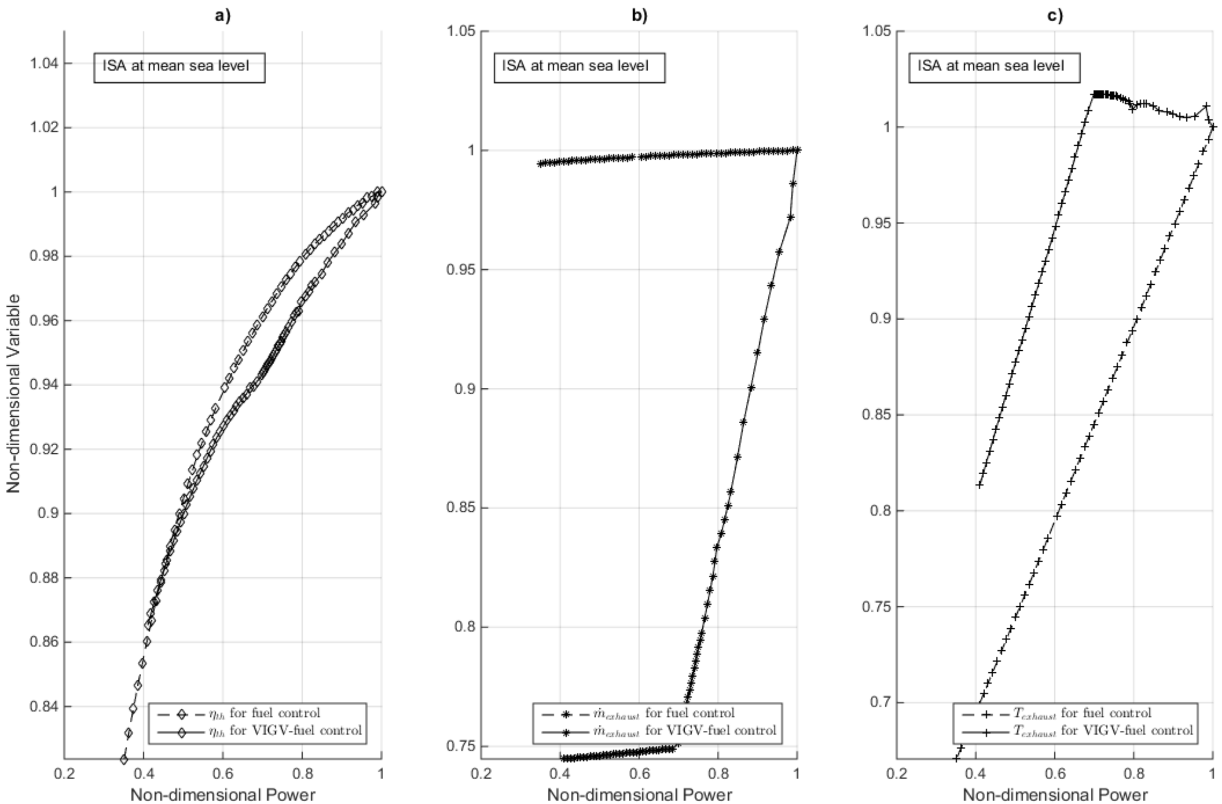
GT simulation

Load reduction methods

1. Fuel active control
2. Turbine entry temperature control
   - TET = const. → Texh increase
3. Exhaust temperature control
   - Texh = const. → TET decrease



GT engine operational map



<u>Risks</u>

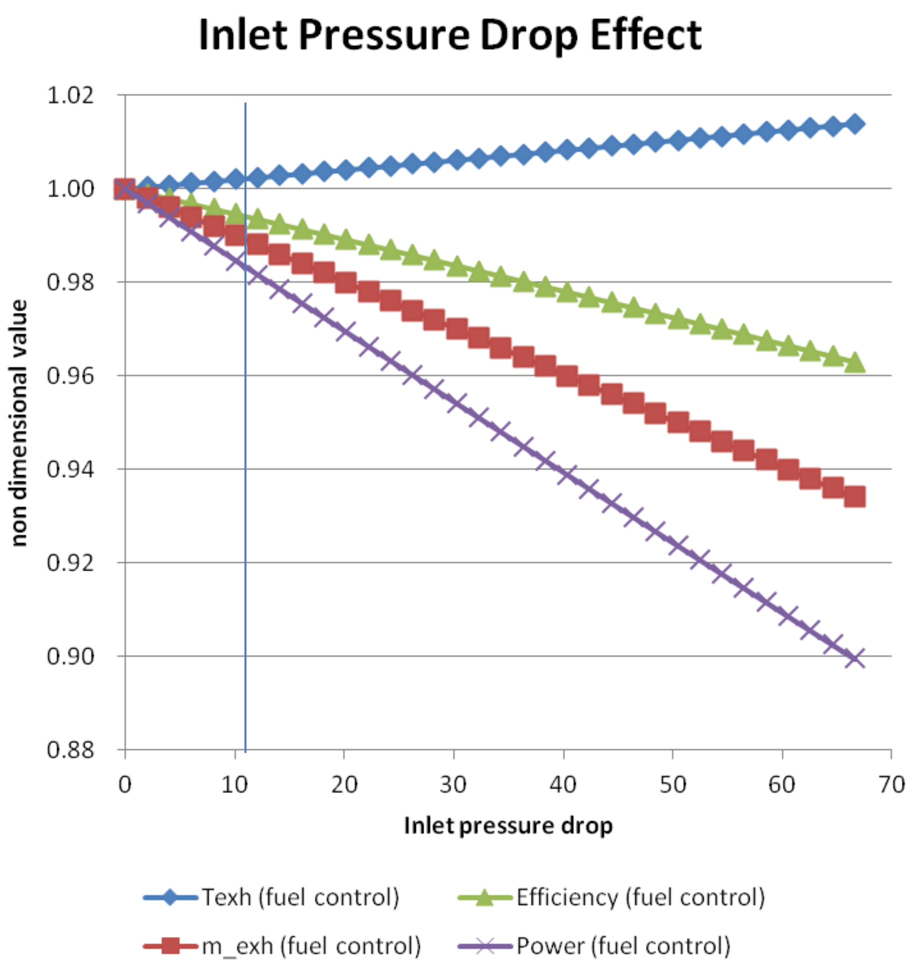
VIGV control only

- Overheating the hot section

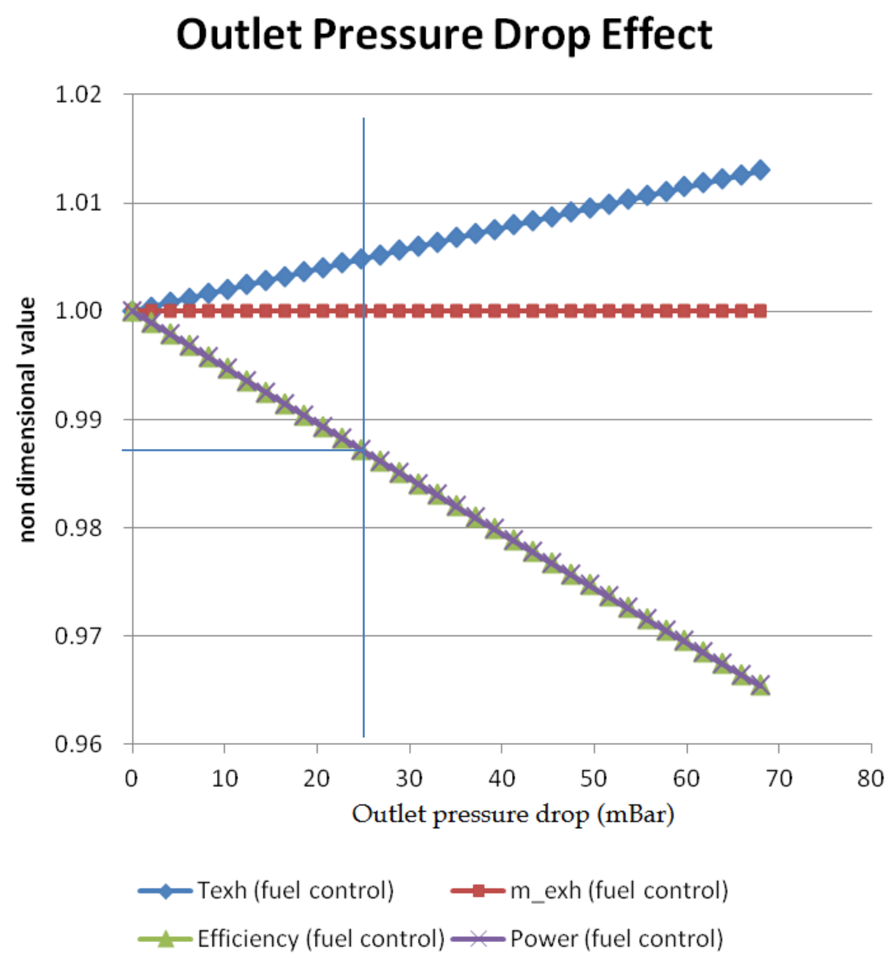
Fuel control only

- Flame out due to excessively lean conditions

GT simulation

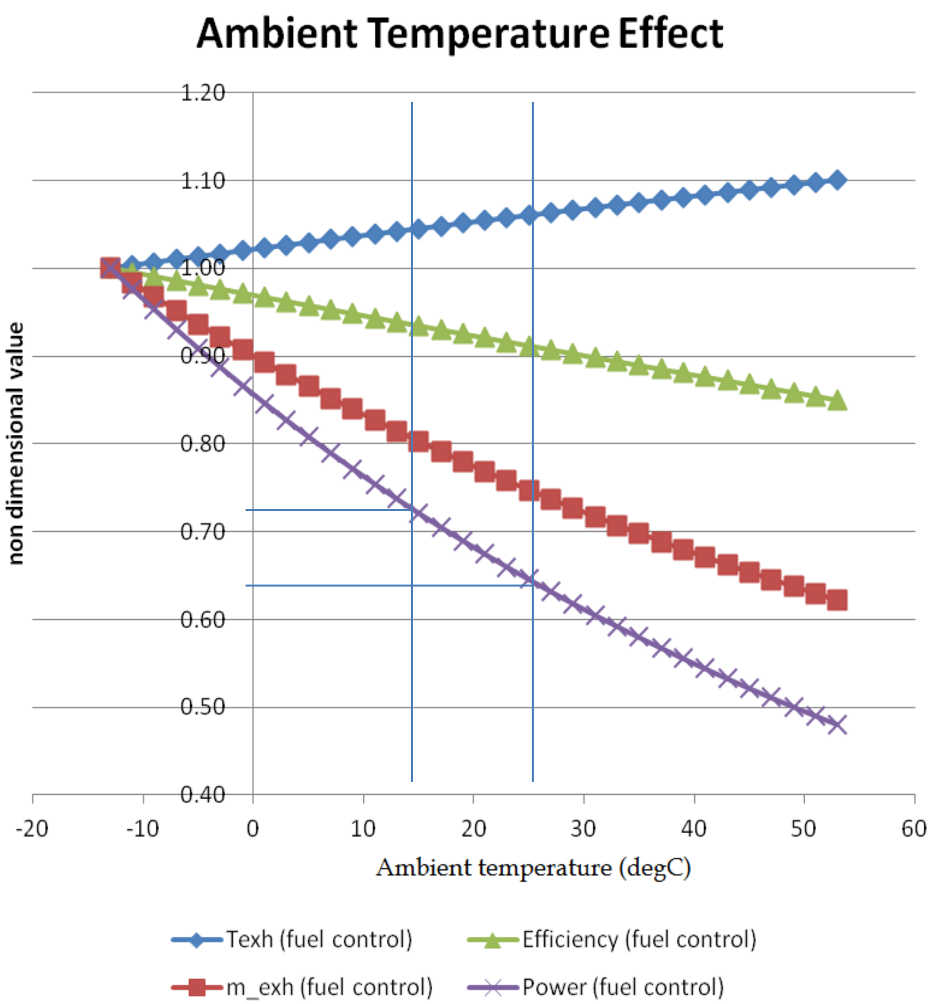


~ 2% Power loss

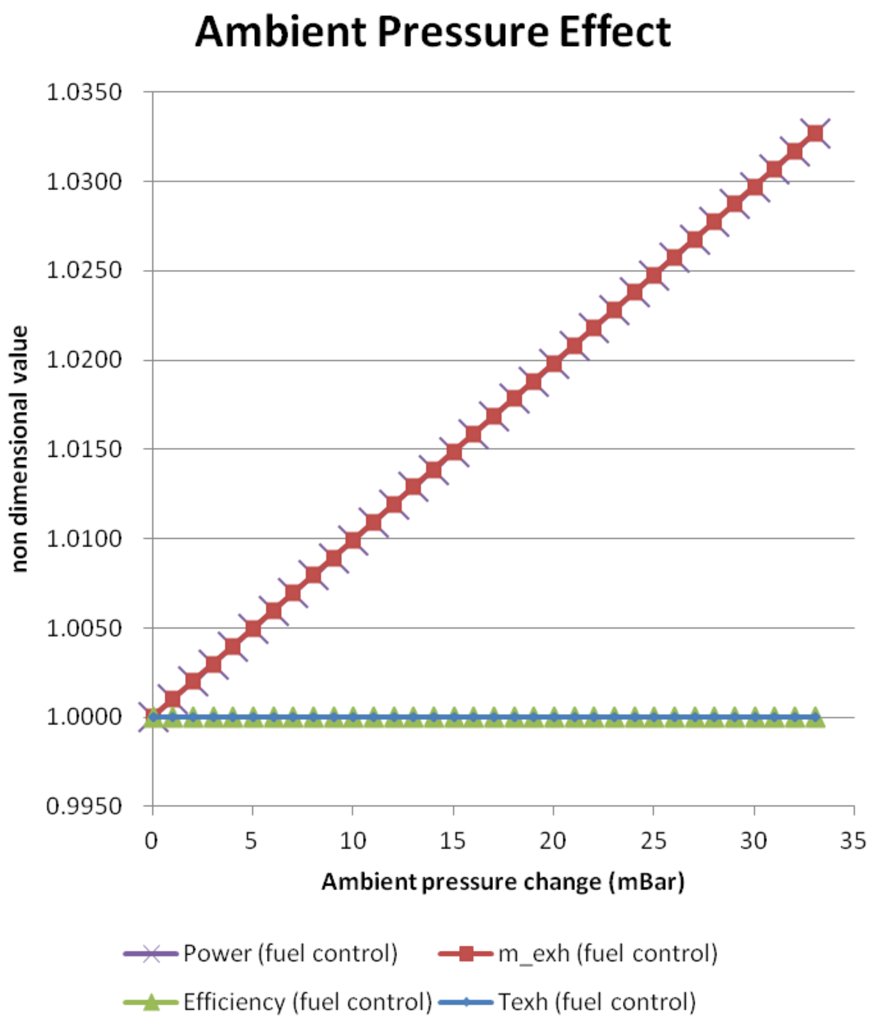


~ 1% Power loss

GT simulation



~ 10% Power loss



~ Power loss in bottoming cycle

GT engine operational map

Case scenario

- 10 mbar drop at inlet (inlet filter)
- 25 mbar drop in exhaust back pressure (HRSG)
- Ambient temperature increase from 15°C – 25°C

↓

13% power loss
e.g. 52 MW lost in 400 MW plant

Conclusion:
Non-dimensional mass flow should represent x-axis in GT Operational Map, not power output

GT engine operational map

- **D**
- N
- Fuel flow
- VIGV
- PO
- **T amb**
- **P amb**
- Load exposure time
- Load change
- Fatigue life consumption
- Creep life consumption

$$\pi_1 = \frac{\dot{m}_{GT}\sqrt{T_{amb}}}{P_{amb}}$$

$$\pi_2 = \frac{TET}{T_{amb}}$$

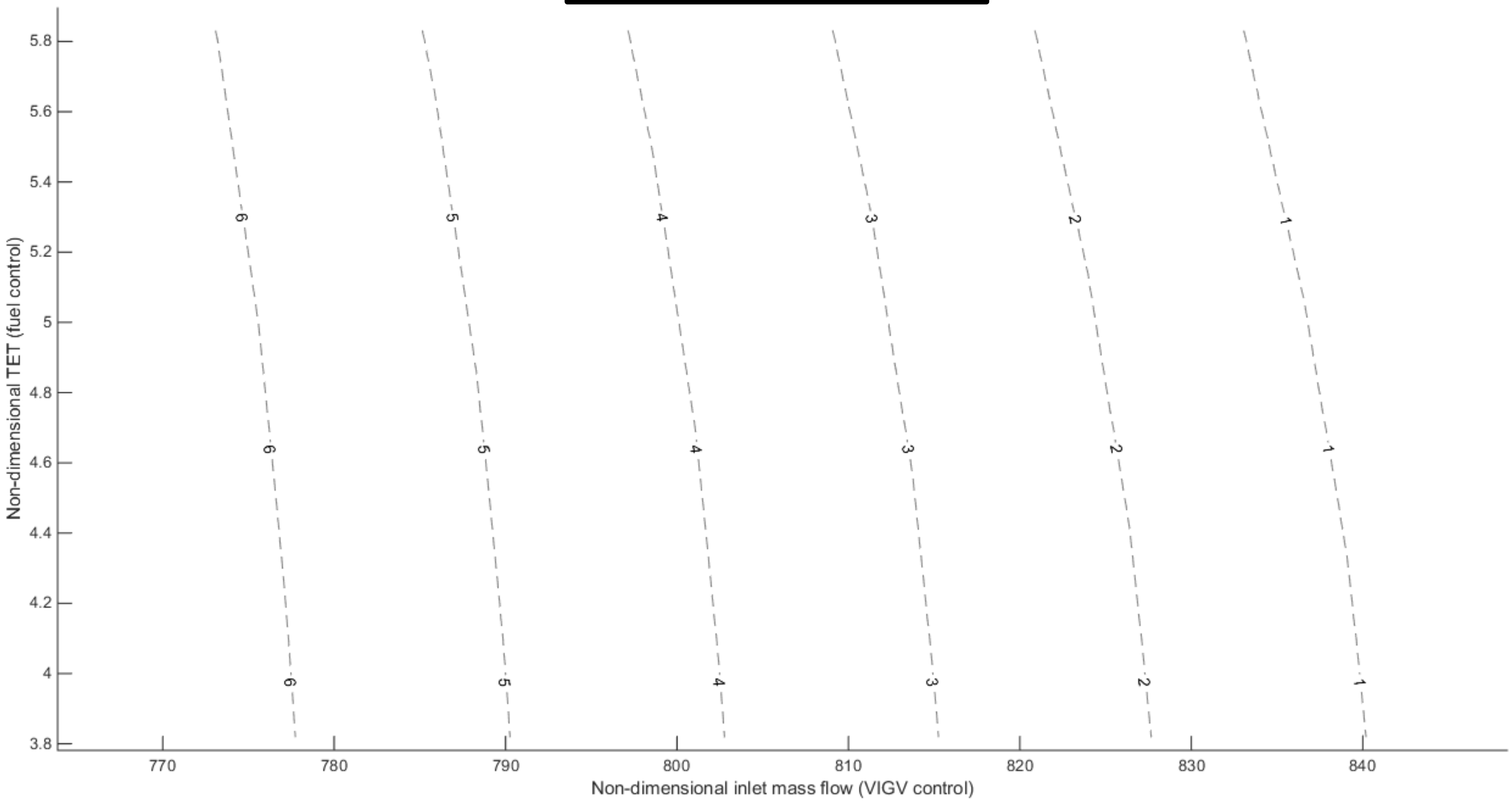
$$\pi_4 = VIGV$$

$$\pi_3 = \frac{{T_{amb}}^{3/2} PO_{GT}}{DP_{amb}}$$

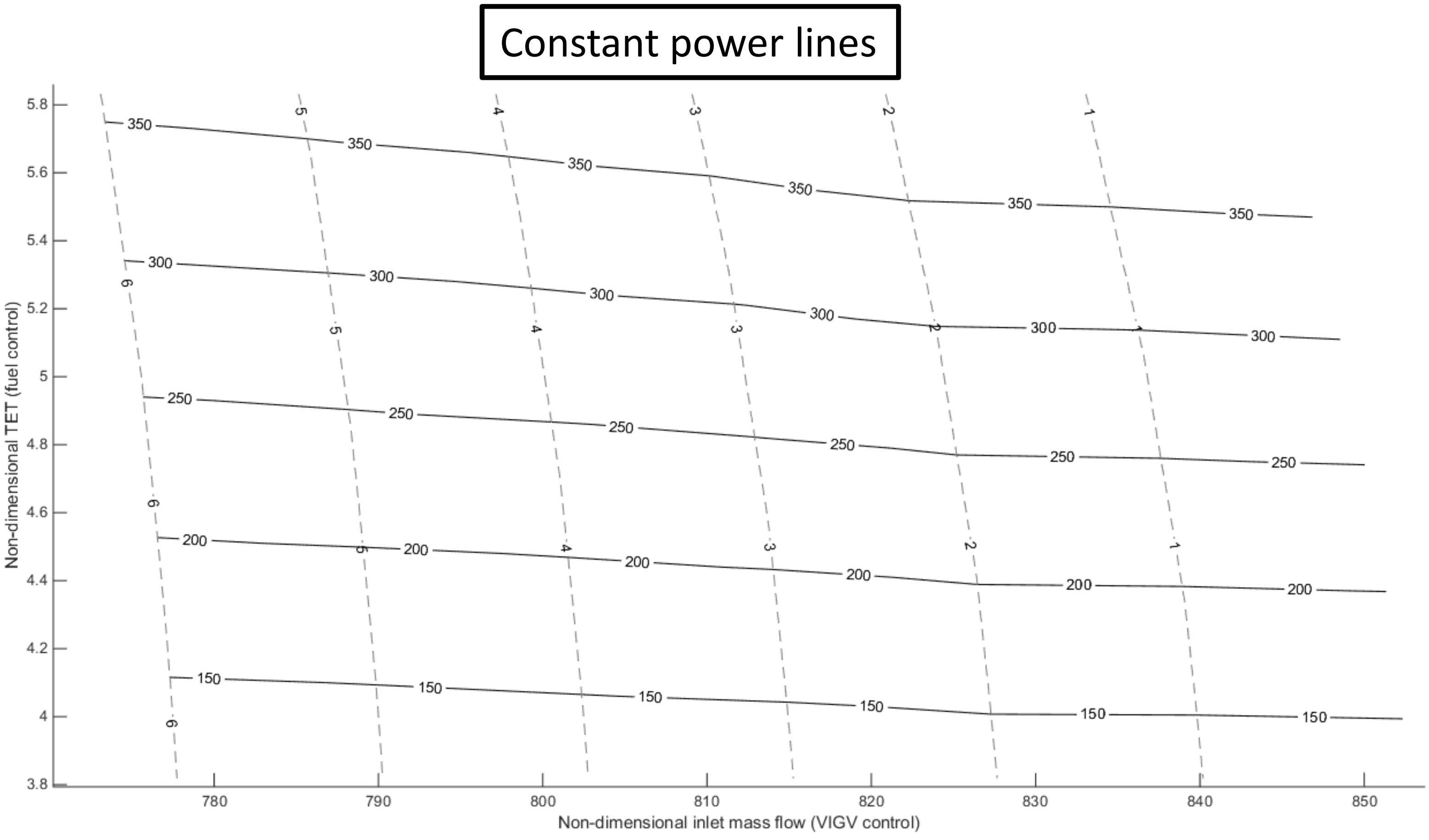
$$\pi_5 = ETA_{GT}$$

GT engine operational map

Constant VIGV lines



GT engine operational map



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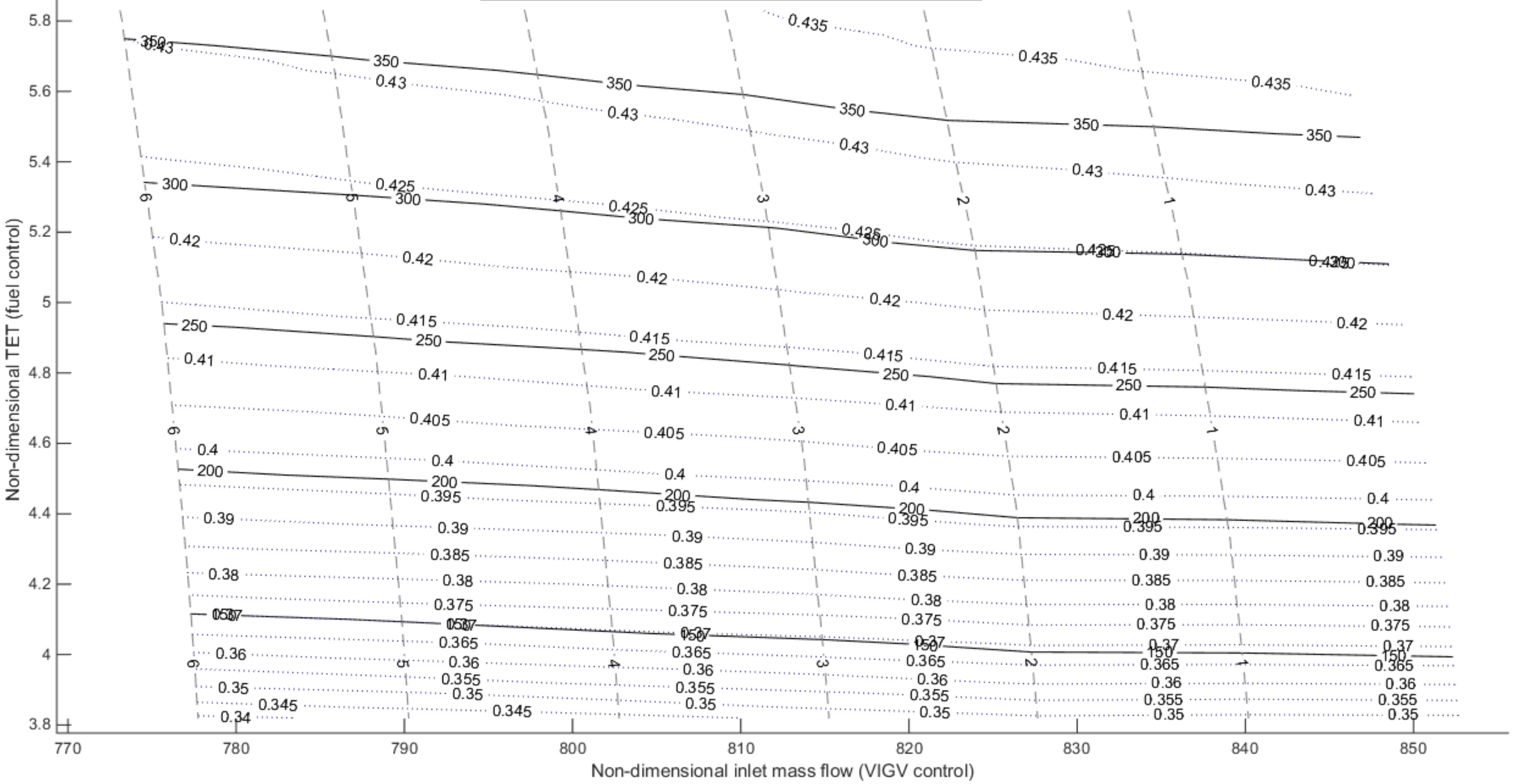
GT engine operational map

Constant efficiency lines



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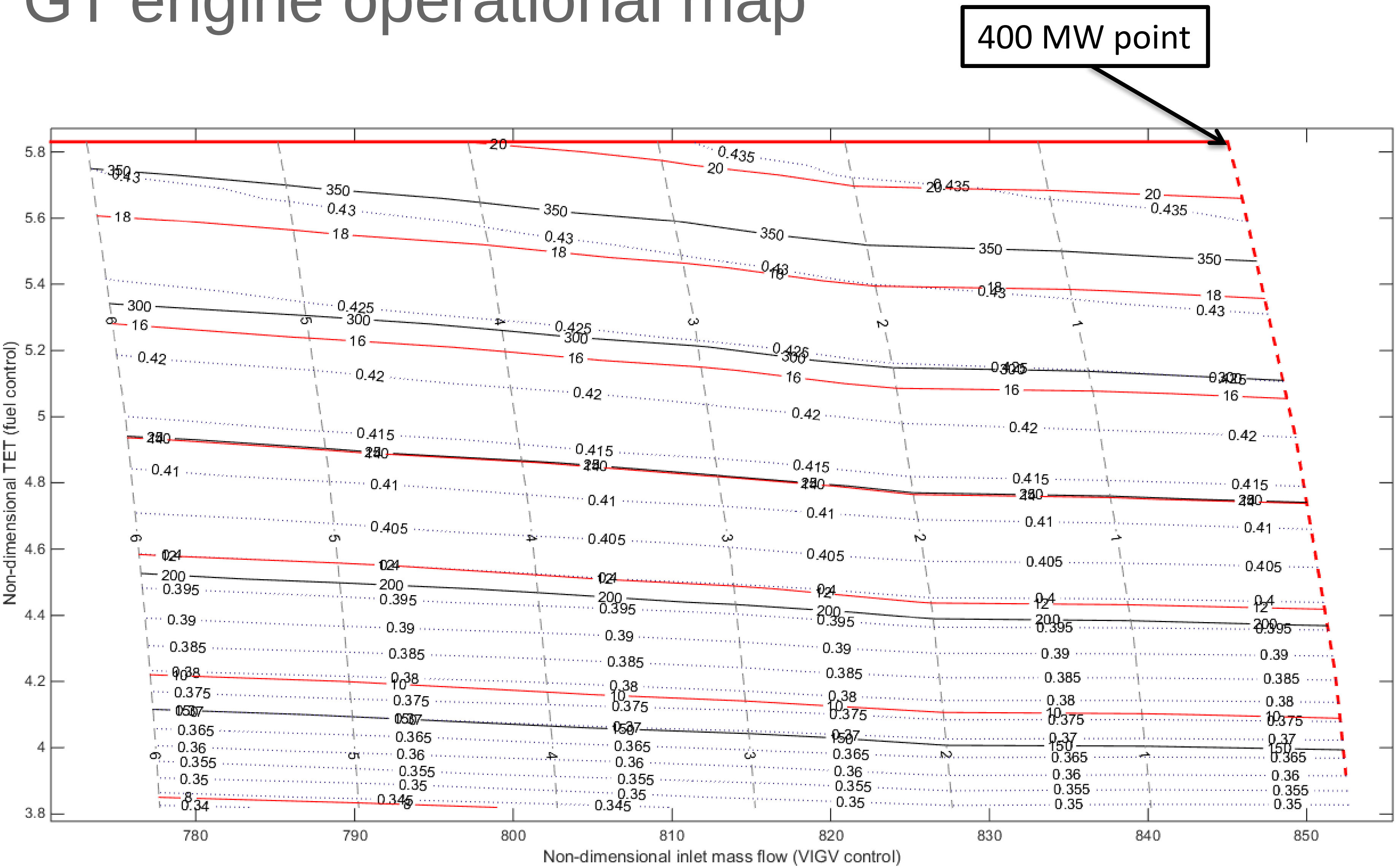
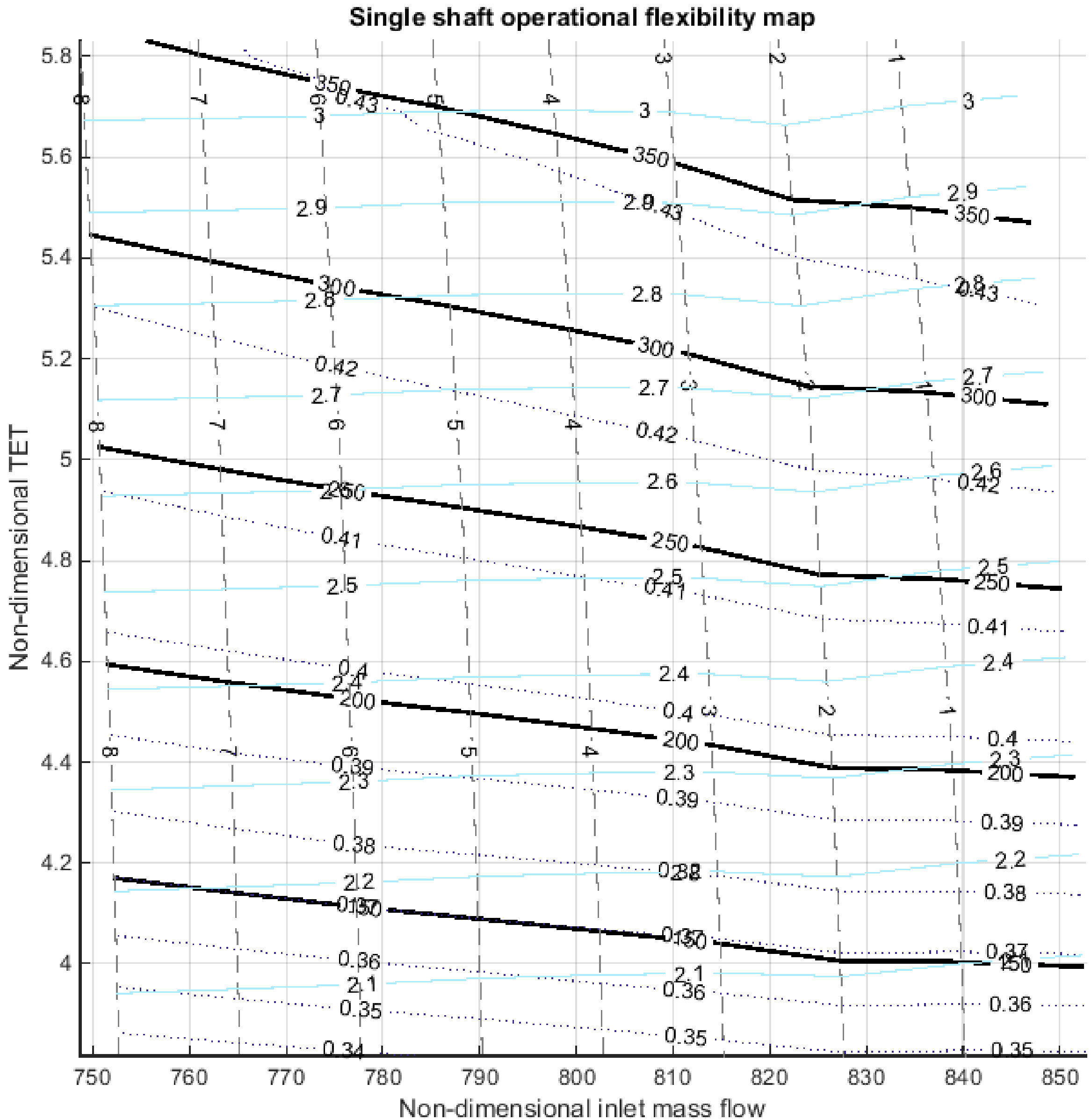
GT engine operational map

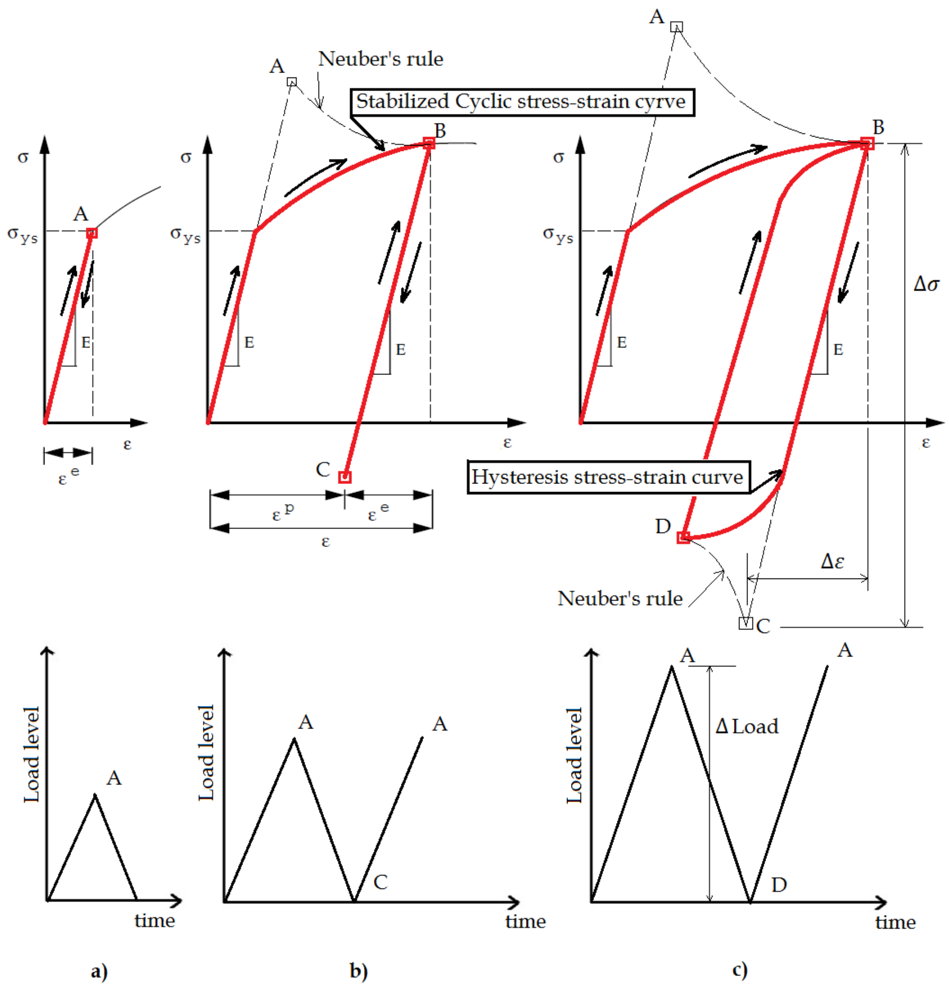


GT engine operational map

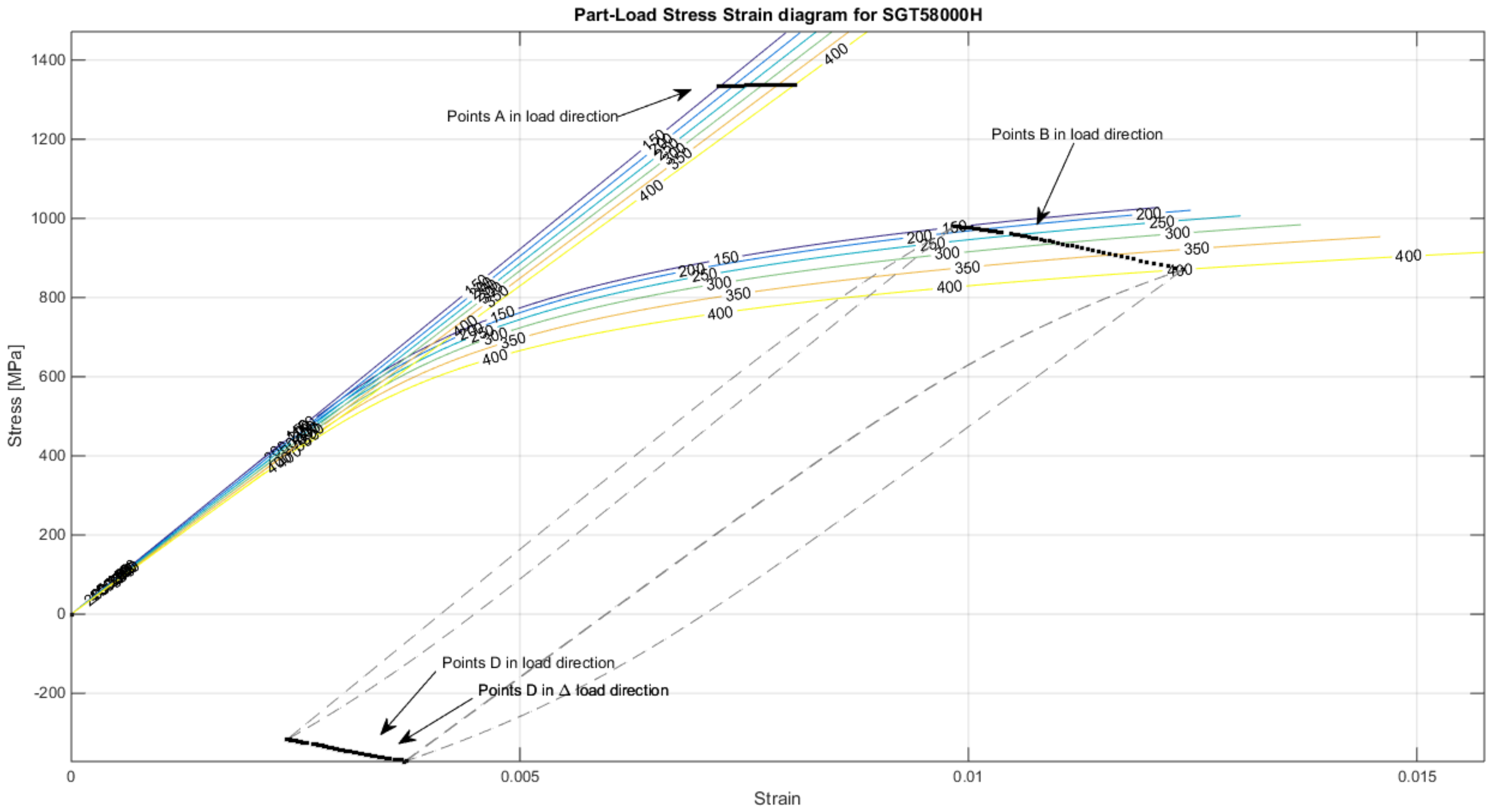


Technical background
– development of lifing map

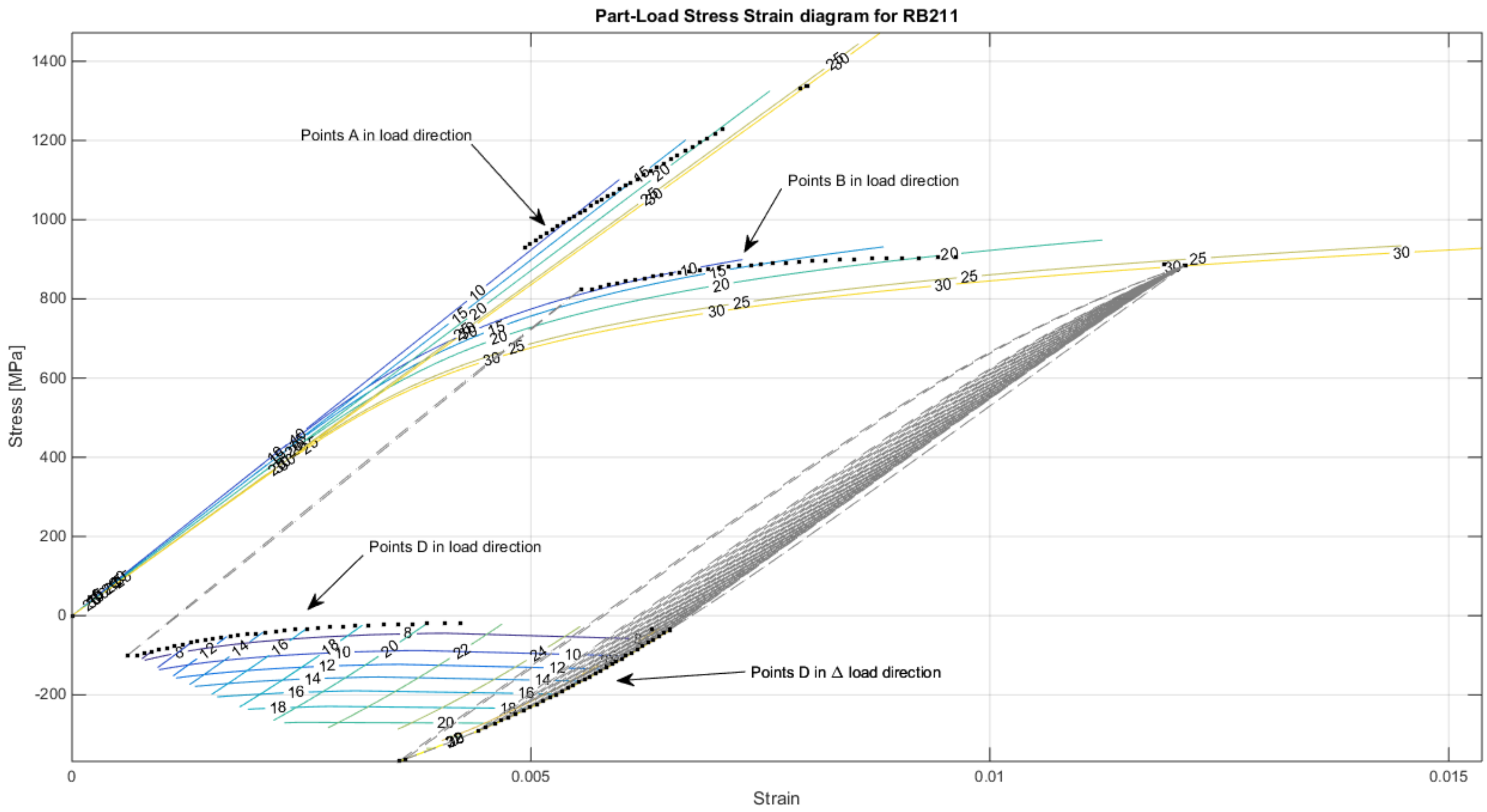
Low cycle fatigue



Low cycle fatigue



Low cycle fatigue



Thank you very much.
Any Questions?