Gas Turbine Flexibility and Life Assessment Method

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Presentation outline

• Balancing analysis
• Technical background
Balancing analysis
Balancing analysis
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

Example:
First
• 400 – 350 MW 0.045% fatigue consumption
• Hold for 1 hour
Then
• 350 – 300 MW 0.033% fatigue consumption
• Hold for 1 hour
TOTAL: 0.078%

x 500 times
39% fatigue consumption
Balancing analysis - creep

National Grid asks:

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

Maintenance schedule based on pre-determined equivalent operating hours

Shift based on dynamic analysis
Technical background
Gas turbine performance

**Single shaft fuel control**

**Single shaft VIGVs-fuel control**

**Multi shaft fuel control**

**Multi shaft VIGVs-fuel control**

Temperature [K] vs Load [MW]

- $T_{\text{TE}}$
- $T_{\text{blade}}$
- $T_{\text{cooling}}$
- NIMONIC115 melting point
Gas turbine performance

**Single shaft fuel control**

**Single shaft VIGVs-fuel control**

**Multi shaft fuel control**

**Multi shaft VIGVs-fuel control**

- Centrifugal Stress
- Centrifugal Stress at a notch
- Ultimate tensile strength
- Young's modulus $\times 10^3$
- Yield strength
Technical background
– development of operational map
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

Risks

VIGV control only
• Overheating the hot section

Fuel control only
• Flame out due to excessively lean conditions
GT simulation

Inlet Pressure Drop Effect

Outlet Pressure Drop Effect

~ 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

Constant power lines
GT engine operational map

Constant efficiency lines
GT engine operational map

400 MW point
GT engine operational map

Single shaft operational flexibility map

Non-dimensional TET

Non-dimensional inlet mass flow
Technical background
– development of lifing map
Low cycle fatigue
Low cycle fatigue
Low cycle fatigue
Thank you very much.
Any Questions?