Gas Turbine - Partload and Operational Tradeoffs

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4 Effectors for turbine operation + one

- Air flow
- T-Fire/Fuel flow
- Pressure ratio
- Turbine/cycle efficiency
- Exhaust Energy
Gas Turbine Effectors / Sensors

What are my effectors?

**Legend:**
- IGV – critical effectors
- TTXM – critical sensors

What are fuel splits?

A “split” is the proportion of fuel that is delivered to a particular combustion gas passage. In any given DLN system configuration with N valves, there are N-1 split effectors (since the sum of the fuel is prescribed by FSR, you lose one degree of freedom in splits).

What is IGV?

IGV stands for Inlet Guide Vanes. IGV (csrgv signal name) refers to the vanes at the compressor inlet that affect air flow. Opening the IGV increases air flow through the compressor and hence the gas turbine.

What is IBH?

IBH stands for Inlet Bleed Heat. IBH refers to recycling compressor outlet flow back to the compressor inlet. IBH acts to increase air flow through the compressor while decreasing air flow through the gas turbine. The primary use is Compressor surge and icing protection.

What is FSR?

FSR stands for Fuel Stroke Reference. FSR is the key fuel control output, configured to be proportional to the fuel heat consumption (BTU/sec). FSR can be thought of as though there it were the position of a single “virtual” gas control valve for the turbine.

Other Critical Control Parameters:
- TFIRE – Firing temperature
- CRT – Combustion reference temperature
- TNHCOR – inlet temp-corrected speed
- CPR – compressor pressure ratio
Every plant decision comes with tradeoffs

- Increase Output
- Raise Efficiency
- Increase Availability
- Reduce Maintenance Costs
- Enhance Flexibility
- Balance Wear & Tear
- Improve Reliability
Stretching or how to get more Flexible
Axial Fuel Staging ("Turndown Enhance")
Greater operating flexibility with improved emissions

<table>
<thead>
<tr>
<th>CTQ</th>
<th>Performance*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Flex</td>
<td>32% H2 content</td>
</tr>
<tr>
<td>Emissions</td>
<td>0.7 ppm NOx or 85% CO reduction</td>
</tr>
<tr>
<td>Turndown</td>
<td>Down to 30% of Baseload</td>
</tr>
</tbody>
</table>

*Estimated values based on NG operation at ISO conditions. Illustrative purposes only.

Potential additional benefits:
- Up to 2% fuel burn reduction at part load
- ~0.4% simple cycle efficiency improvement
- Peak fire up to +100°F while remaining NOx compliant (alternative to turndown capability)
- Wider ambient temperature emissions compliance

✓ Extends the combustion system by 8”
✓ Applicable to both DLN1 and DLN1+
✓ Available to quote
Axial Fuel Staging ("Turndown Enhance")

<table>
<thead>
<tr>
<th>Hardware</th>
<th>AFS CM&amp;U</th>
<th>Difference between DLN1+ LN and ULN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secondary Fuel Nozzle</td>
<td>May use existing parts</td>
<td>Transfer Style</td>
</tr>
<tr>
<td>Endcover Assembly</td>
<td>May use existing parts</td>
<td>Identical</td>
</tr>
<tr>
<td>Combustion Casing</td>
<td>May modify existing casing</td>
<td>Identical</td>
</tr>
<tr>
<td>Liner</td>
<td>Modify or buy new</td>
<td>Identical</td>
</tr>
<tr>
<td>Flow Sleeve</td>
<td>Modify or buy new</td>
<td>Identical</td>
</tr>
<tr>
<td>AFS Injectors</td>
<td>New part</td>
<td>Identical</td>
</tr>
<tr>
<td>AFS Thimbles</td>
<td>New part</td>
<td>Identical</td>
</tr>
<tr>
<td>Transition Piece</td>
<td>Use existing design</td>
<td>Different dilution holes</td>
</tr>
<tr>
<td>Cross-Fire Tubes</td>
<td>New part</td>
<td>Identical</td>
</tr>
</tbody>
</table>

![Graph 1](image1.png)

![Graph 2](image2.png)
Features and benefits

**DLN turndown enhance**

- Reduced NO\textsubscript{x} (~25%) – concurrent NO\textsubscript{x} and CO emissions reductions also achievable with compliant operations
- Extended CO compliant turndown\textsuperscript{2} – from 60% to 35% of peak load\textsuperscript{1}
- Emission compliant peak fire\textsuperscript{2} – additional output – Up to +100°F T_\text{fire} increase with same current NO\textsubscript{x} levels\textsuperscript{1}
- Improved ambient operating range \textsuperscript{1}
- Combustor pressure drop reduction – up to .4% improvement in SC efficiency\textsuperscript{1}
- Part-load simple cycle efficiency – up to 2% fuel burn reduction (higher air and pressure ratio) \textsuperscript{1}
- Commonality/flexibility/tunability – reduced need for dilution retunes\textsuperscript{1}

Operational flexibility, increased output and efficiency – retrofittable

\textsuperscript{1}Compared to current 9E DLN combustion system without DLN Turndown Enhance
\textsuperscript{2}Emission compliant peak fire cannot be combined with Extended compliant turndown
Using power of Digital for Flexibility
Upgraded fundamental control technology

Baseline DLN1 control

- Single temperature control curve - multiple operational boundaries implicit
- No corrections

Corrected Parameter Control

- Four separate calculations for primary boundaries: Performance, Tfire, CO, NOx
- Corrections for ambient temperature, humidity, inlet/exhaust pressure drop
- Additional sensors; humidity & ambient TCs

CPR – Compressor Pressure Ratio
CTD – Compressor Discharge Temperature
CMHUM – Specific Humidity
DPin/ex – Inlet and Exhaust Pressure Drop

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Enhance DLN Performance

**AUTOTUNE LT & DX**
- Correct parameter control – tighter control (Tfire, NOx, CO, dynamics)
- Automated fuel split adjustments
- CEMS feedback optional (DX)

**AUTO RECOVER from primary re-ignition**
- Automatic vs. manual discovery
- Load reduction of ~5% vs. ~50%
- Automatic return to premix ~15 seconds vs. 10-30 minutes
TRIP AVOIDANCE

• Improved logic to avoid trips
• Intelligent signal selection and use
• System level data validation
• Alternative protective actions

Examples

– Exhaust spread and over-temperature logic
– Secondary flame detector sensing logic
– Transfer purge protection
– Valve position faults
– Null bias compensation for gas control valve
– Enhanced vibration sensing and logic
Identify faults before startup
OpFlex* Start Assurance

STARTING RELIABILITY
• Start permissive rationalization
• Pre-start system checks
• Start sequence display showing start process status
• Check system at any time upon command

START PERMISSIVE SWEEPS PROVIDING HIGHER RELIABILITY

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Predix*: Connecting Data and People Throughout the Organization

Accessibility | Scalability | Ecosystem | Custom Apps

Maintenance Manager  Plant Manager  Asset Manager  Trader  CEO

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Efficiency optimizer: How it works

Edge UI
Configured to take user inputs on current ambient and target plant output conditions; ability to run in manual or auto-optimize mode.

Digital twin
Physics models and tracking filters to match the physical plant; feeds the optimizer with plant cycle parameters to solve for best HR setpoints.

Optimizer
Periodically solves for minimum plant heat rate (HR) by generating optimized supervisory setpoints ("cycle levers") for the key production assets in the power plant. The result is reduced fuel consumption from part load to baseload relative to the plant’s baseline operating conditions.
Digital delivers additional efficiency between intervals

1 time HR improvement
Post outage from Major inspection and AGP

+ 0.5 % with Digital

Upgrades provide benefits post outage
Digital adds ongoing value between intervals
Constantly tuning for best operating setpoints given ambient conditions, fuel composition at base load and part load

Heat rate decrease due to AGP

Current HR
New AGP
Digital optimized
Questions?