Industrial Application of Gas Turbines

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Optimizing Pipeline Station Fuel Efficiency Using Turbine Split and Degradation Calculations

By

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Introduction

- Motivation:
  - Maximize pipeline fuel efficiency by selecting optimal turbine outputs.
- Complex, non-linear problem:
  - Many choices!
    - Which stations to run, load setting for each turbine?
  - Need to consider different parameters:
    - Ambient conditions, flow delivery requirements.
    - Station/unit combinations
    - **Gas Turbine Degradation**

Introduction

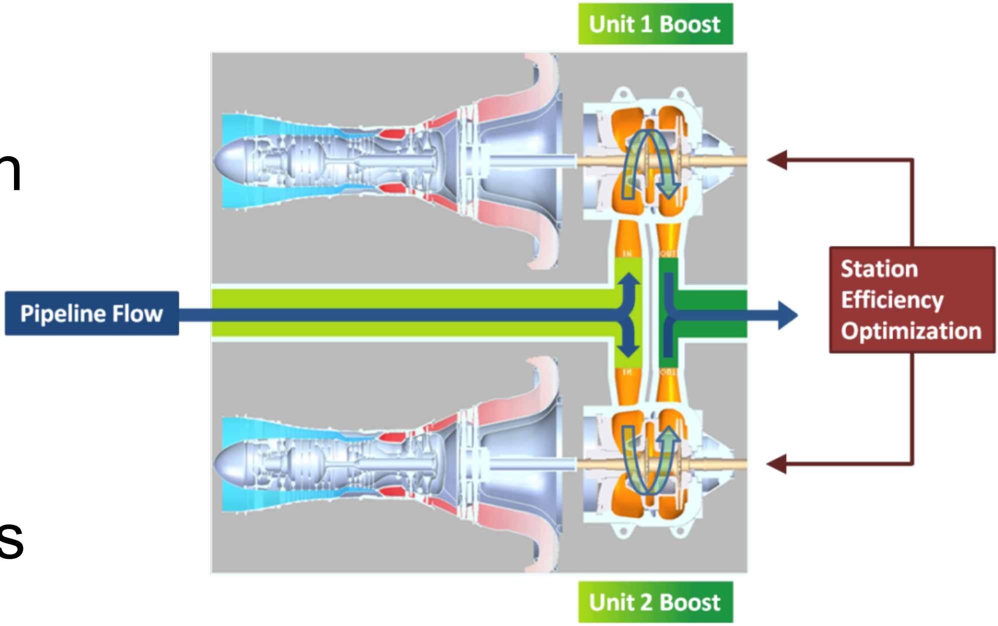
- We can optimize fuel efficiency of pipeline when excess capacity exists
  - Requires the ability to choose which units and stations run
  - Computer assisted numerically optimized solution

Optimization

- Are you running optimally?
- Typical strategy assumes all units / stations perform nominally / as-designed.
  - Most turbines are sold with minimum performance guarantees.
- Does not consider the performance conditions of the units / stations.
  - A highly degraded turbine can consume up to 5% more fuel than a new turbine.

Typical Pipeline Optimization

- Example:
  - Consider gas compressor station with two identical turbines
- Two approaches:
  - Equal loading
  - One loaded, other picks up excess demand.



Typical Pipeline Optimization

Equal Loading

- Each of the units perform an equal share of the work.
- Both units power up/down the same amount as demand changes.
- Does not consider differences in unit performance

One online, 2^{nd} for Excess

- Keep one unit running as high as possible
- Second unit brought online when first is max.
- Differences in unit performance can be leveraged for fuel savings.

Equal Loading

- Balanced work (head) between units.
  - Throttling not required.
- Both units are run equally (sub)optimal
  - Depending on conditions, would it be better to run one at a higher load and disable the second?
- Ignores differences in unit degradation
  - Higher fuel consumption

One online, 2nd for Excess

- Unequally loaded:
  - Station requires throttle valves to balance head.
- Primary unit can maintain peak efficiency
  - Lower fuel consumption
- Maintenance challenges:
  - First unit reaches fired hours limit, second unit will reach start limit.
- Can consider unit degradation (but doesn't)

What is Degradation?

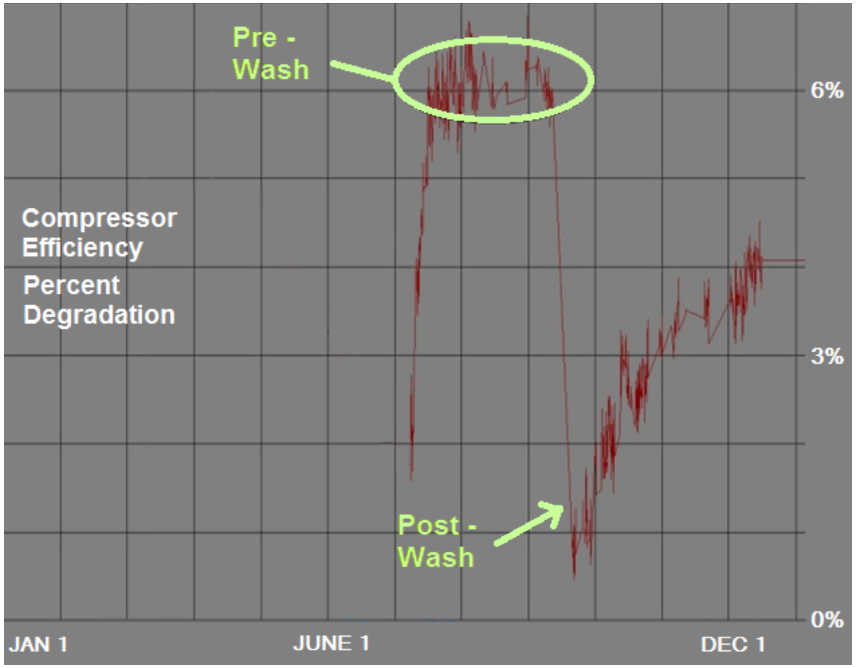
- Deterioration in quality, level, or standard of performance of a unit.
  - Simply: increased heat rate (more fuel per unit output)
- Two types:
  - Catastrophic: abrupt change, serious event.
  - Graceful deterioration: result of the normal wear and tear a unit experiences over time.
    - Will help optimize performance

Turbine Efficiency Degradation

- Three components contribute to overall turbine degradation:
  - Turbine efficiency degradation
    - Gradual changes in components in hot gas path.
      - Material loss, tip clearance changes, accumulation of particles etc
  - Swallowing capacity degradation
    - Change in volumetric flow into turbine due to creep of first stage vanes.
  - Compressor degradation

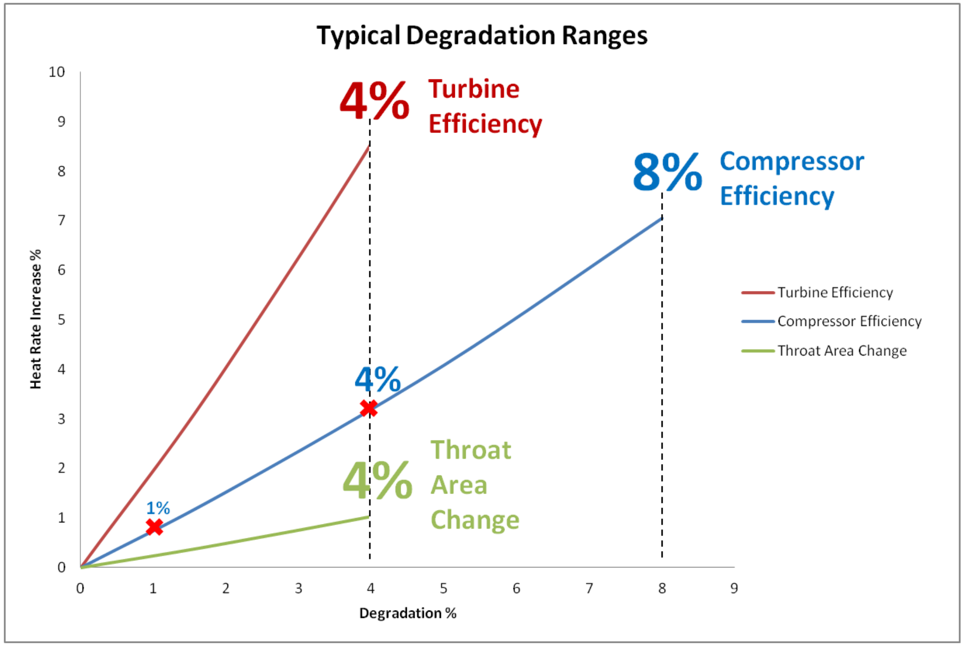
Compressor Degradation

- Two components:
  - Temporary
    - Compressor is dirty.
    - Wash.
  - Permanent
    - Erosion of airfoil surfaces due to abrasive particles



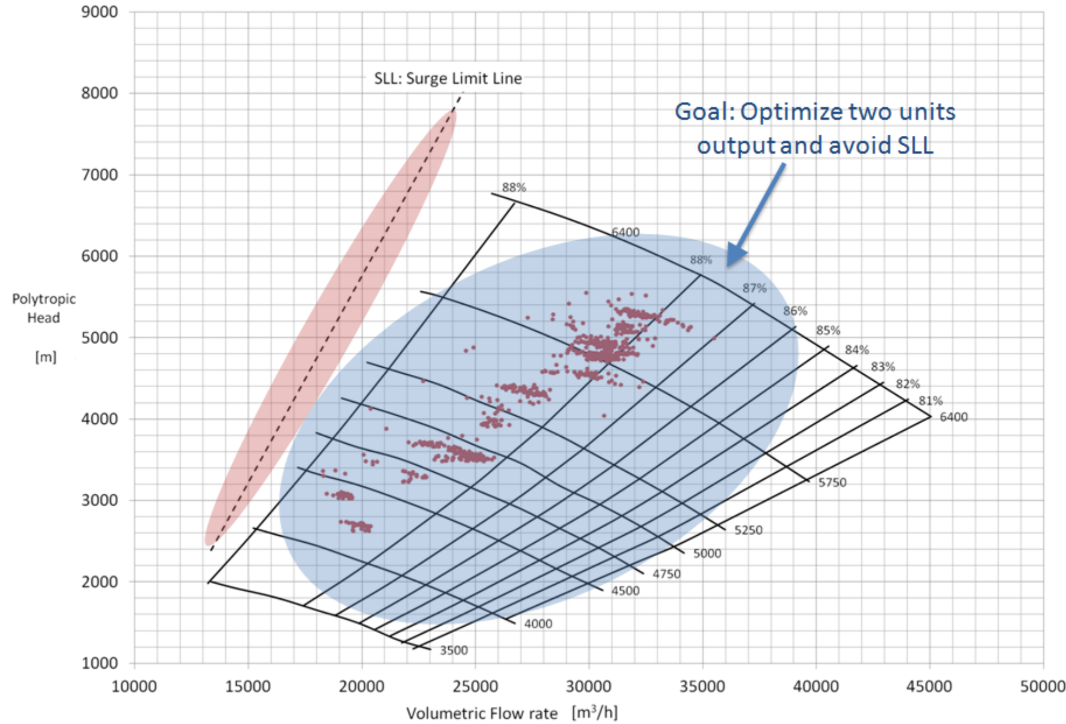
Effect of Degradation

- Effect of degradation on overall heat rate
- Turbine has largest overall effect but…
  – Compressor degradation occurs sooner



Effect of Degradations

- Typical head vs. flow curve
- Knowing the exact turbine condition will affect efficiency for a given RPM.



How is Degradation Calculated?

- With a precise, physics based, turbine model.
  - Uses published performance data combined with instrumentation data (actual conditions).
  - Expected “new and clean” performance vs. actual performance.
    - Difference in these numbers is degradation.

Optimization with Degradation

- With the calculated performance degradations, a better optimization strategy can be employed.
- Solution:
  - Prioritize units with the best performance first.
  - Run the most efficient stations first.

Station Optimization Example

- Consider identical 27 MW turbines driving axial flow compressors
  - Unit 1 is performing “as-new” with 0% degradation
  - Unit 2 and 3 – Increased compressor degradation → higher heat rate
- Running Unit 1 instead of Unit 2 or Unit 3 will result in significant fuel savings per year

Power	27			MW
Thermal Efficiency	37%			
Comp. Degradation	0%	2.00%	5.00%	
Heat Rate Increase	0%	1.64%	4.24%	
Heat Rate	73.0	74.2	76.1	MJ/s
Fuel Price (2014 Market Avg)	$4.39			USD/MMBTU
	$4.16			USD/GJ
Cost Rate	$26,214	$26,644	$27,327	$/d
	$9,568,034	$9,725,223	$9,974,187	$/y
	Cost Savings (per year)			
	$157,189		X	
	X	*$248,964*		
	$406,153			

Application

- Liburdi CEHM
  - Compressor Equipment Health Management
  - System currently installed and running on Petrochina's West-East Pipeline
- Pipeline consists of:
  - Rolls Royce RB 211 and GE LM2500
  - Validated physics model accurately computes turbine degradations.

CEHM

- CEHM provides collection and storage of data in a secure, central location where it is easy to retrieve and analyze.
  - Operational data is valuable.
- CEHM is a scalable, expandable platform.
- CEHM provides state of the art tools for determining equipment condition and life analysis. This results in optimized maintenance intervals, opportunities for improving pipeline operations and reduced operating cost.

Additional Benefits

- Emissions monitoring, diagnostics
  - Calculation of NOX
- Component life monitoring
  - Extend components when in part load conditions.
- Event trending and alerts
  - Does that data excursion spell trouble?

Thank you!

Questions?