An introduction to Intelligent Combustion Control

The benefits of lean premixed combustion systems to reduce NOx emissions are well demonstrated in industrial gas turbines. Since the development of the DLE combustion system, a predefined fuel schedule was in place to control the ratio of fuel delivery between the pilot & main burners across the load range.

Predefined fuel schedules are conservative and do not take into account any site specific issues, variations or system drifts, which can result in warnings/trips and/or regular onsite tuning activities. Using predefined fuel schedules also prevents the engine from running with optimum NOx emissions. A considerable amount of time may also be lost during the Works Acceptance Test (WAT) and onsite commissioning to find a schedule that is suitable.

Intelligent combustion control is a control algorithm that automatically adjusts the pilot split (within predefined limits) to reduce high levels of low frequency (band 1) combustion dynamics and/or high burner tip temperatures during normal steady state running.

The intelligent combustion control monitors the flame through existing combustion instrumentation. The most responsive parameters to control the operational window were found to be the burner temperature and the pressure dynamics.

Applicable to Gas Fuel and Dual Fuel DLE versions of the SGT-300 and SGT-400 Small Gas Turbines.

Fig. 1 Schematic of combustion and control systems showing input and output to the close-loop control algorithm.
Although NOx levels are not directly controlled or monitored by the intelligent combustion control, it is expected that by being able to run with a leaner pilot split map, lower levels of NOx emissions can be achieved with Intelligent combustion control being able to compensate for any combustion dynamics.

Running in close proximity to the lean blow-out limit in turn results in the optimum (lowest) NOx, without affecting CO readings.

The engine design is known to have non-operational regions that will result in a trip.

The split map is set during commissioning.

During operation, the engine systems are known to drift (i.e. STAR Fuel Valve) that could result in shifting non-operational regions so that it overlaps the split.

The split map does not always compensate for ambient temperature changes. If it was set for high ambients during commissioning, then in winter it could result in engine tripping.

Why use Intelligent Combustion Control?

When band 1 dynamics or high tip temperatures are experienced (the pilot split is offset from the nominal), normally there is a physical reason for it:

1. Drift or leakage within the fuel metering system (i.e. with the STAR Fuel valve)
2. Burner leaks / blockage
3. Fluctuations of gas fuel composition, gas pressure and ambient temperature

Introducing Intelligent Combustion Control will address some of the problems (i.e. case 1 or 3), and will compensate for other issues in the short term (i.e. case 2).

Solution: Intelligent combustion control will compensate for:

1. The drift (until the valves are serviced)
2. Minor variations in the burner flow area due to leaks or blockage
3. Fluctuations in ambient conditions and fuel composition
How does intelligent combustion control work?
- Intelligent combustion control works by determining an offset to the nominal split map stored within the software.
- Operating range is divided into a number of bands with a different offset for each band allowing for minimal reshaping of the split map.
- Offsets are limited based on the current operating bands.
- Applied offset is ramped from the currently applied offset to the new required offset upon transitioning between bands.
- Instead of running against a fixed predefined schedule line, the optimum split will be identified from the operational field.

Advantages of Intelligent Combustion Control
- Reduced number of flameouts (can flame failure) during works acceptance test, commissioning and engine operation.
- Enhanced engine reliability during transient loads
- Expected reduction in NOx levels
- Reduced number of warnings for:
  - Burner tip temperatures
  - High Band-1 dynamics
- Intelligent Combustion Control will run reliably at the optimum pilot split for lowest NOx avoiding any other engine limitations.
- Risk is considered to be MINIMAL as the Active Pilot Software will change the pilot fuel schedule within predefined limits and cannot cause detriment to the engine performance.

Fig. 3 Intelligent Combustion Control – Default and Re-shaped fuel schedules

- Standard Fixed Pre-set % Pilot Split
- Where changes in: Fuel CV / Fuel Temperature / Fuel Pressure / Component drift/tolerances (fuel pump) / Specific site conditions, could lead to either the High Band 1 dynamic limits fluctuating to cause flameout or a failure of the combustion can(s) due to high tip temperature fluctuation limits.

- New Intelligent Combustion Control
- Where the % pilot split automatically follows the site fluctuations giving optimum performance limits, flame stabilisation and increased reliability. As a result, optimum (lowest) NOx levels are achieved.
Previously: Used predefined fuel schedules, for operation on differing Wobbe Index (WI) fuels: i.e. Natural Gas and Processed Landfill Gas. The graph in Figure 4 presents a number of the predefined fuel schedules which would have been required for operation at different WI.

Predefined fuel schedules were set. This required several maps to cope with the different fuel compositions.

Currently: Reset split fuel schedule using Intelligent Combustion Control.

The graph in Figure 5 presents the field of the fuel schedule available to the intelligent control algorithm to operate within. The algorithm continually responds to the inputs, changing the pilot split within this field, to ensure the optimum operating condition.

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