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Training – Gas Turbine Controls Theory Basics

Brett Butler, TC Energy

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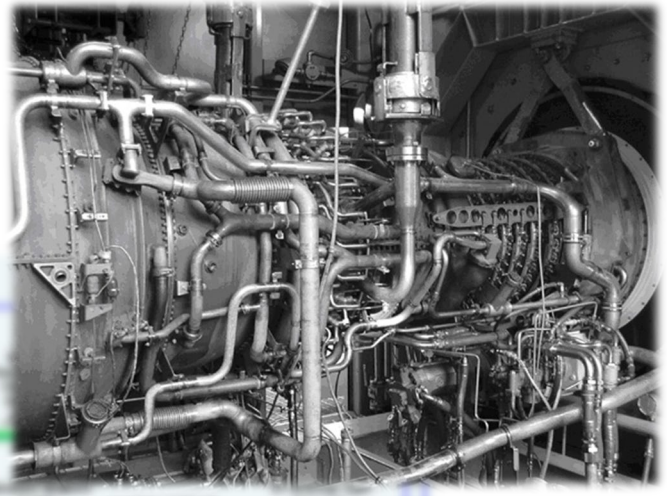
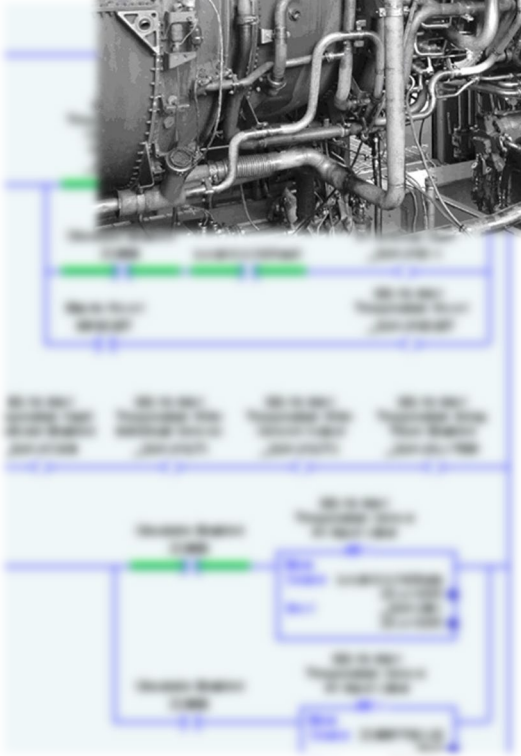
Session Outline

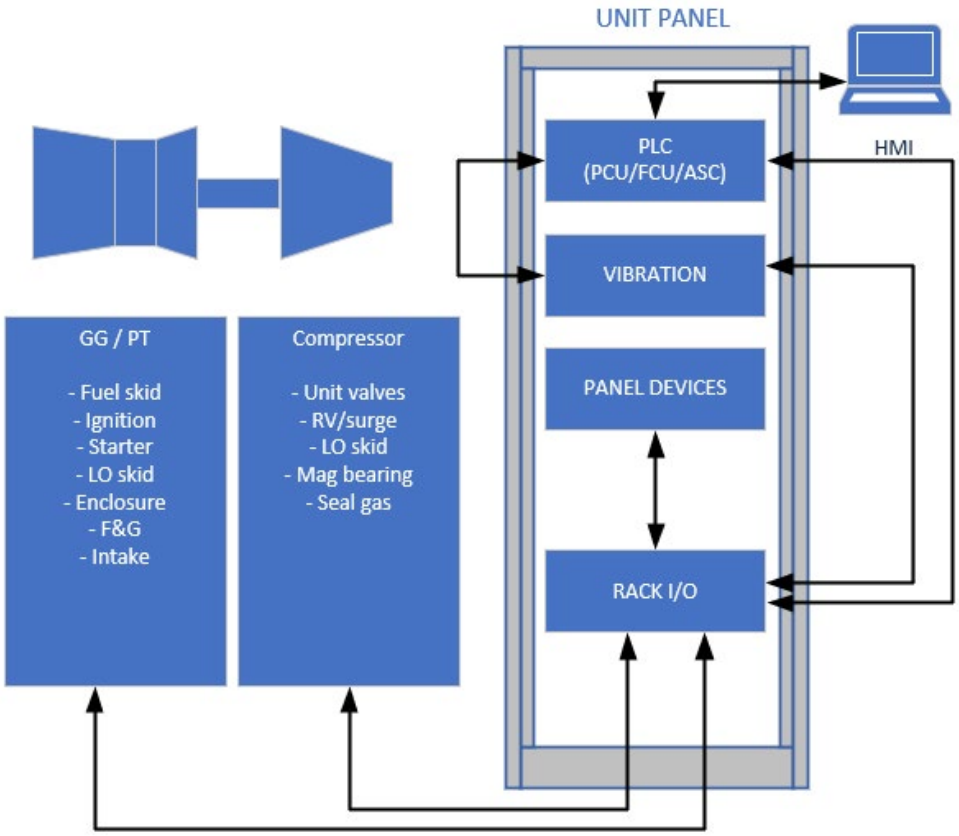
- Gas Turbine Control System Components
  - Package control, Anti-surge, Vibration, Fuel Control
- Fuel Control Operational Description
  - Fuel Control envelope requirements
  - Variable geometry control
- Instrumentation Overview
  - Program I/O used, selection and alarm voting
- FCU Control Philosophy
  - Overall selection
  - Control governors used





Unit Control System – Main Components

- Package Control (PCU)
  - Unit Sequencing
  - Auxiliaries Fire and Gas Protection
- Fuel Control (FCU)
- Gas Compressor Surge Control (ASC)
- Vibration Protection (GG, PT, gas comp, acoustics)
- Operator Interface – HMI or panel devices
- Backup trip – overspeed, ESD p/b, vibration trip

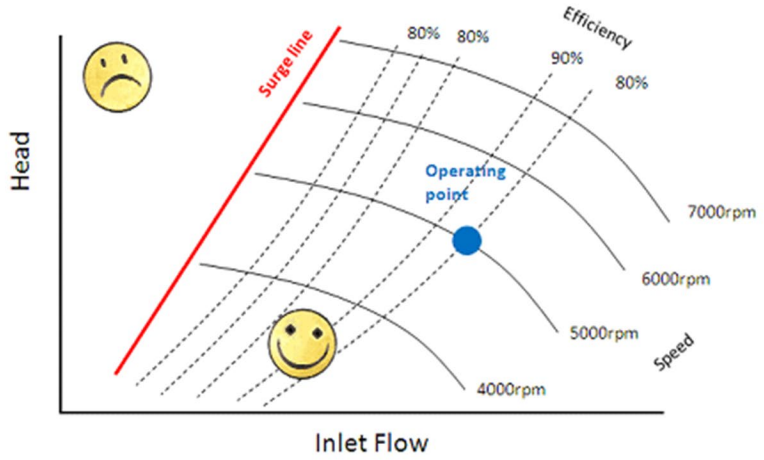


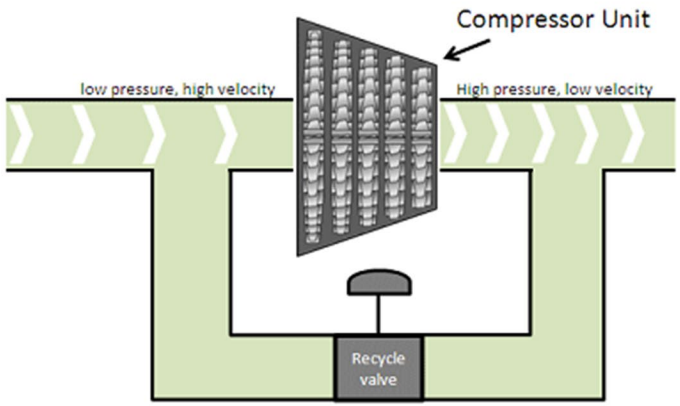
Package Control Unit (PCU)

- Main functions for the PCU are safe operation of the gas turbine and given compressor
- Unit sequencing
  - Unit valve sequencing (suction/discharge/purge/vent/emerg)
  - Start/normal stop sequence
  - Loading/unloading
- Auxiliary systems control
  - Fuel skid, Starter, Ignition, LO skid, enclosure systems (fans/heaters), intake, fire and gas
- Protective functions – alarm/shutdown
  - Shutdown sequences – shutdown, step-to-idle, coolstop, ESD
- Data mapping between systems – HMI, other PLC's (FCU, station), Vibration

Anti-Surge Control (ASC)

- Compressor Surge control
  - Low pressure/high velocity converted to high pressure/low velocity gas
  - The compressors need to be protected against surge
  - Use the recycle valve to control operating point
- ACU works by
  - Disabled until the Load Sequence, LOAD=ON
  - Additional protection available control line, warning and trip line
  - Ensures Compressor Flow remains high enough to prevent surge, even for multiple units



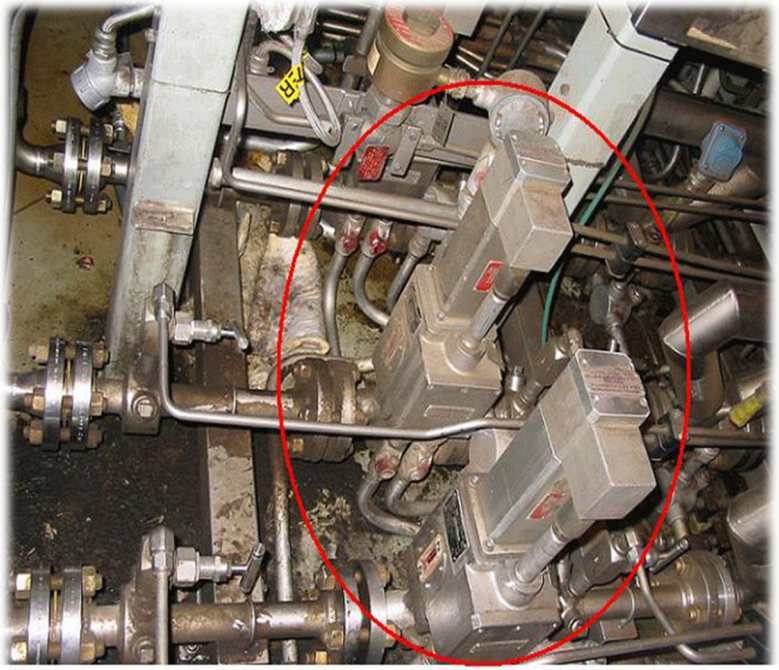


Vibration Protection

- Main functions of the vibration monitoring system
  - Input vibration related sensors (velocity and accelerometers, proximeters, tachometers, temps)
  - Input signal conditioning and processing (lo/hi pass filters) monitored against OEM limits
  - If limit exceedance is detected, protective relays de-energize (alarm or FFSOV closes for trip)
  - Hardwired trip-multiply/reset to VMS
  - Display indication

Fuel Control (FCU)

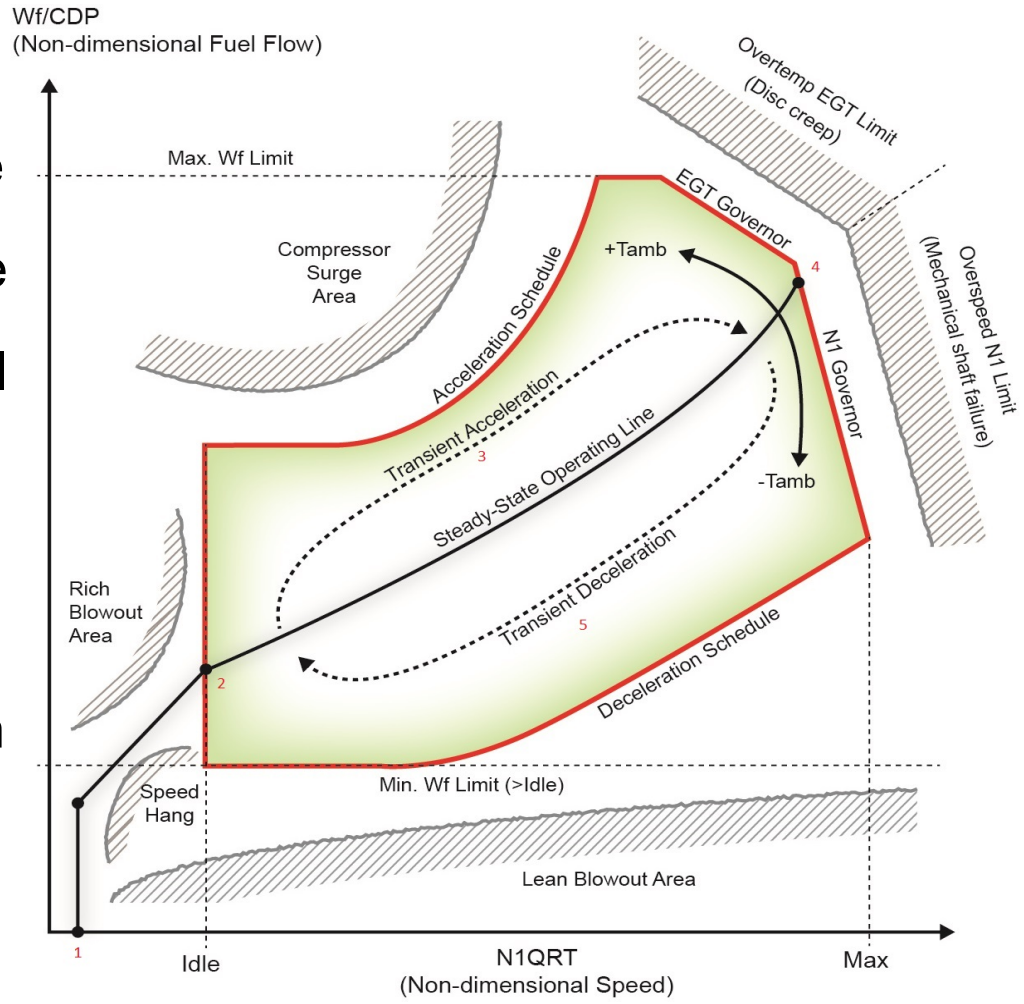
- I/O Signal conditioning/voting
  - N1, N2, N3, EGT, T1, CDP, FGMP, control feedback
- PLC rack that processes the GG I/O and acts on the input commands (fuel on, speed setpoint)
  - Start to idle fuel flow scheduling
  - During normal operation keep turbine within physical limitations (shaft speeds, EGT, power)
  - Safe control during transient maneuvers (accel/decel, minimize overshoot, load/unload rates)
  - Continuous safety monitoring and/or shutdown
- Controlling devices are fuel valve and variable geometry



Fuel control valves

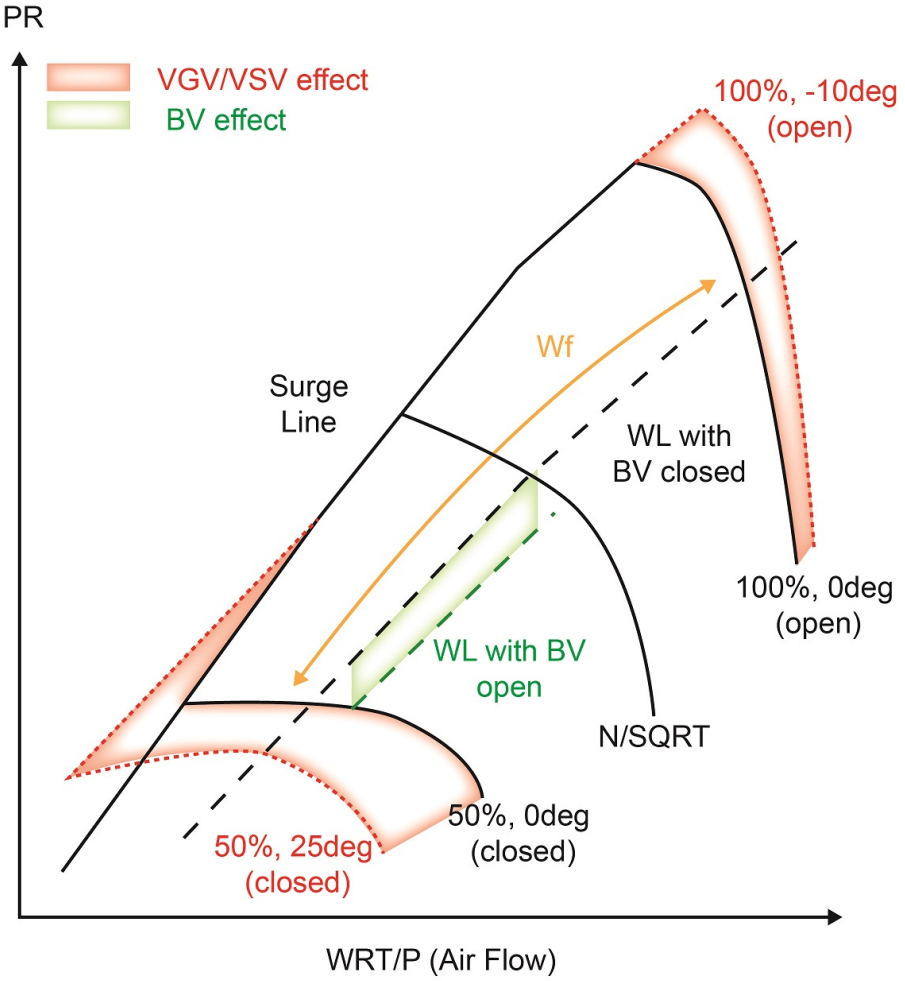
Fuel Control Envelope

- Fuel flow control
  - Varying fuel flow to the engine using a throttle valve
  - HSS valves to chop fuel to the engine in an emergency trip
  - Valve position feedback signal
- Red boundary show the FCU protective limits
  - Shaft overspeed
  - EGT over-temperature
  - Combustor flameout detection
  - CDP stall/surge
  - Shaft speed stagnation

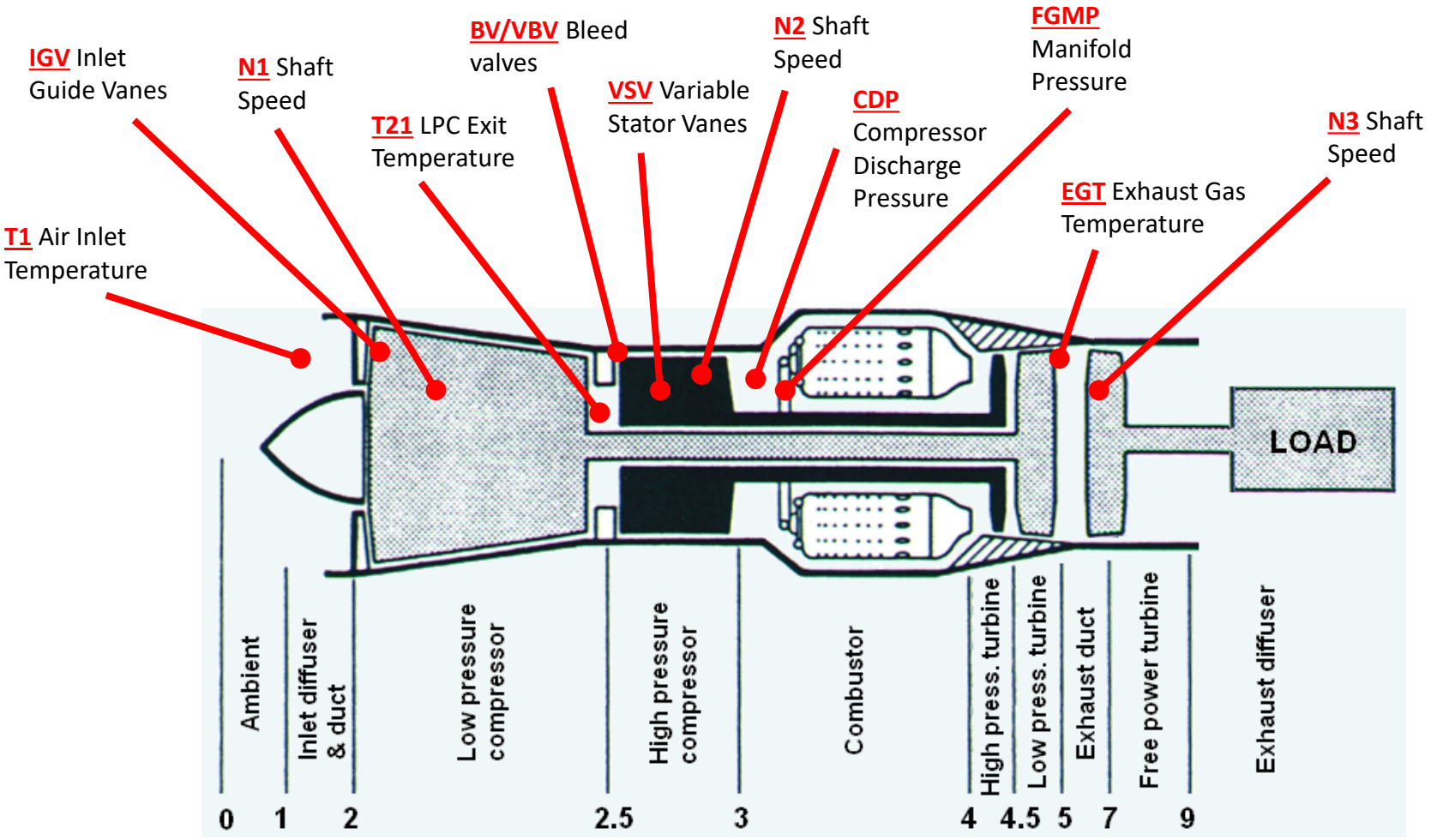


Variable Geometry (air) Control

- Air flow control to improve operability of engine off-design point
- Variable vane geometry
  - modulates the airflow direction through the compressor
  - for same speed at a lower power on the working line, the compressor can achieve a lower flow and PR
- Bleed valves
  - dumps compressed air that effectively drops the working line away from the surge line
- 2 compressors
  - acts to ease the flow restrictions as the HP spool runs at a higher speed than the LP spool
  - reducing choke in the rear stages of the compressor



Instrumentation Overview

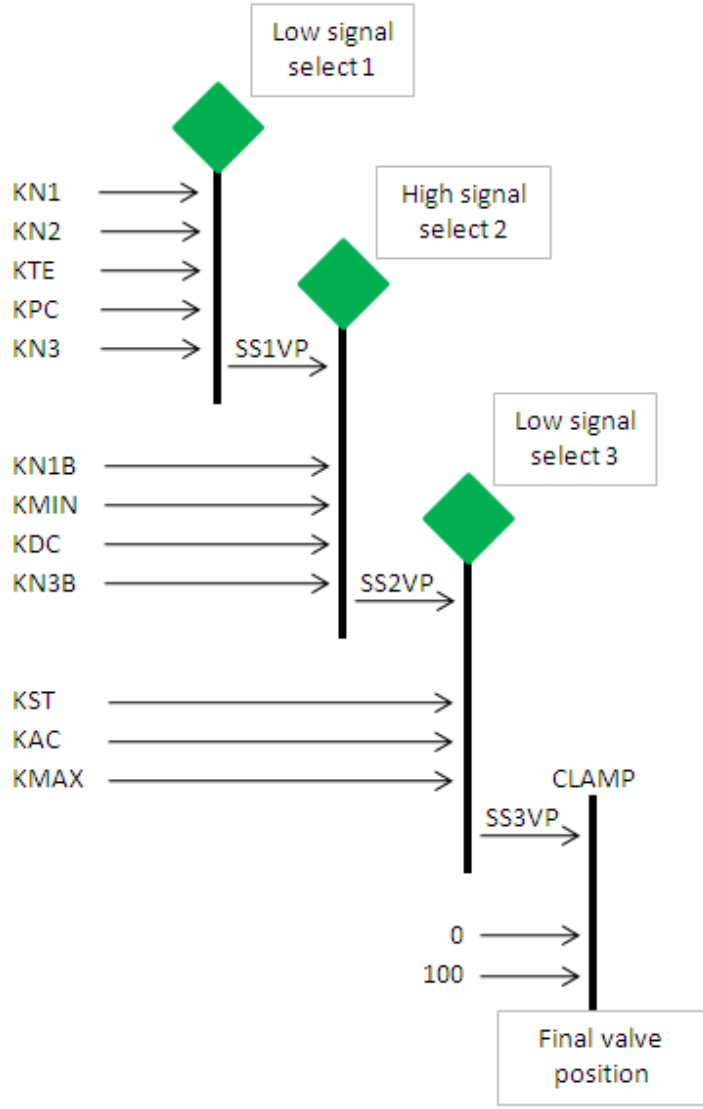


FCU Logic Overview

There are many controllers that interact. At any given time, only one controller will actually control the fuel valve position:

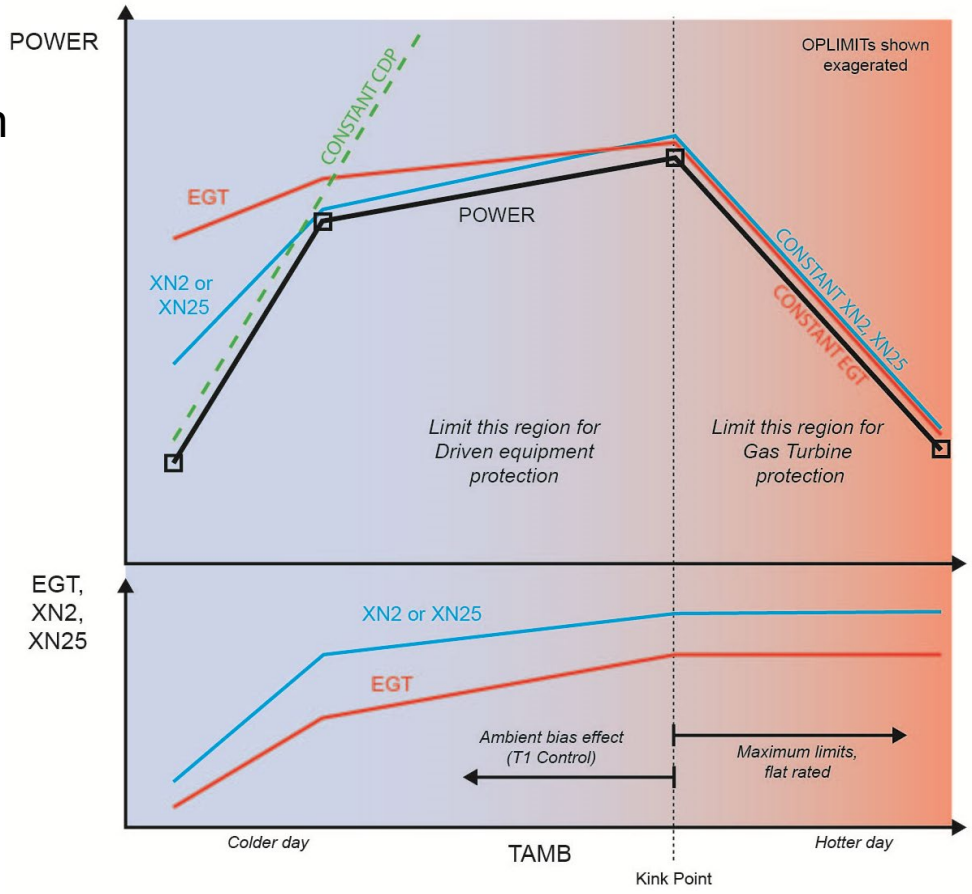
- KN1 LP Compressor Speed Control
- KN2 HP Compressor Speed Control
- KTE Temperature Control
- KPC Compressor Pressure Limiting
- KN3 Power Turbine Speed Control
- KN1B Compressor Speed Bottom Control
- KMIN Minimum Fuel Limiting
- KDC Deceleration Limiting
- KN3B Power Turbine Speed Bottom Control
- KST Starting Fuel Ramp
- KAC Acceleration Limiting
- KMAX Maximum Fuel Limiting

Various controllers go through a low, high and low signal selector gate, only the 'winning' signal passes through to give the final valve demand position



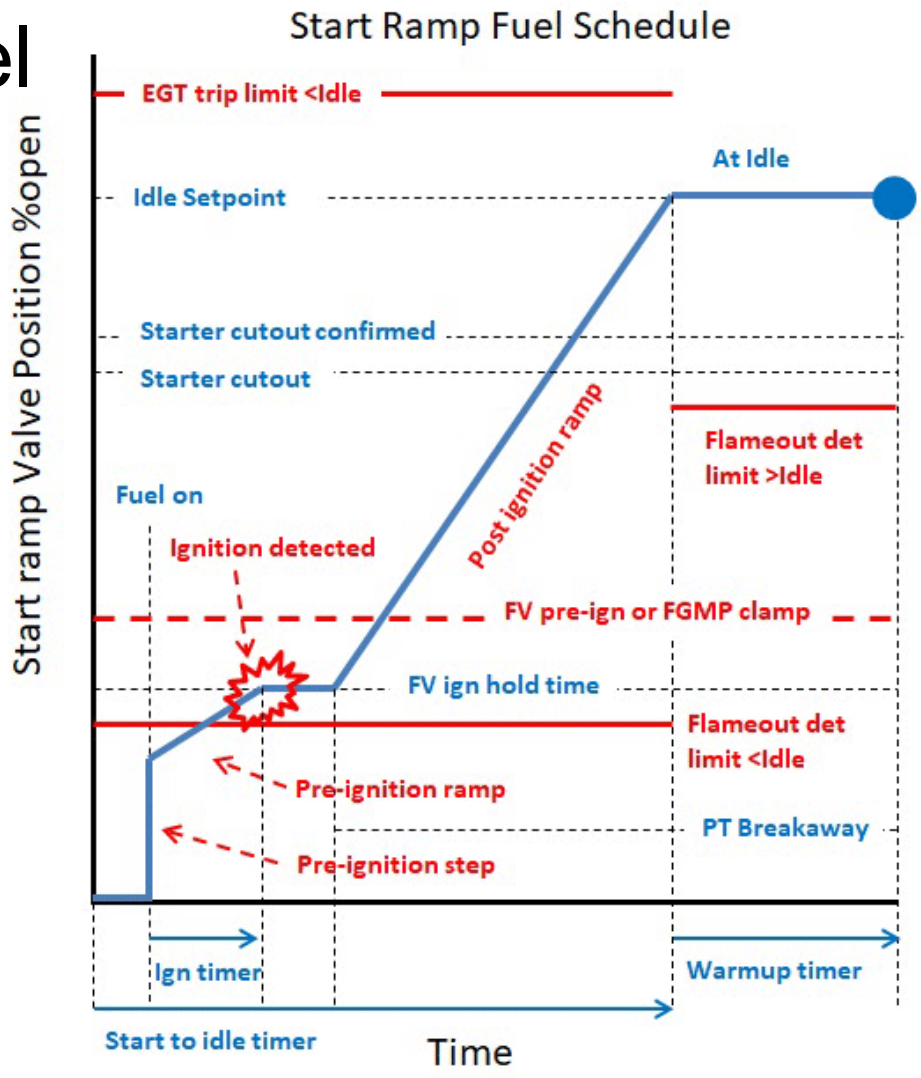
Air Temperature Effects

- Ambient effects
  - Output Power decreases dramatically with increasing air temperature – Operations concern
- Conversely
  - Output Power increases dramatically with decreasing air temperature – Concern about power rating of driven equipment
- Figure shows
  - The black line represents the maximum power rating of the equipment
  - As the air temperature falls below the kink point, the turbine can produce more power than the driven equipment can handle
  - Fuel Control must watch out for this by limiting engine speed at lower temperatures



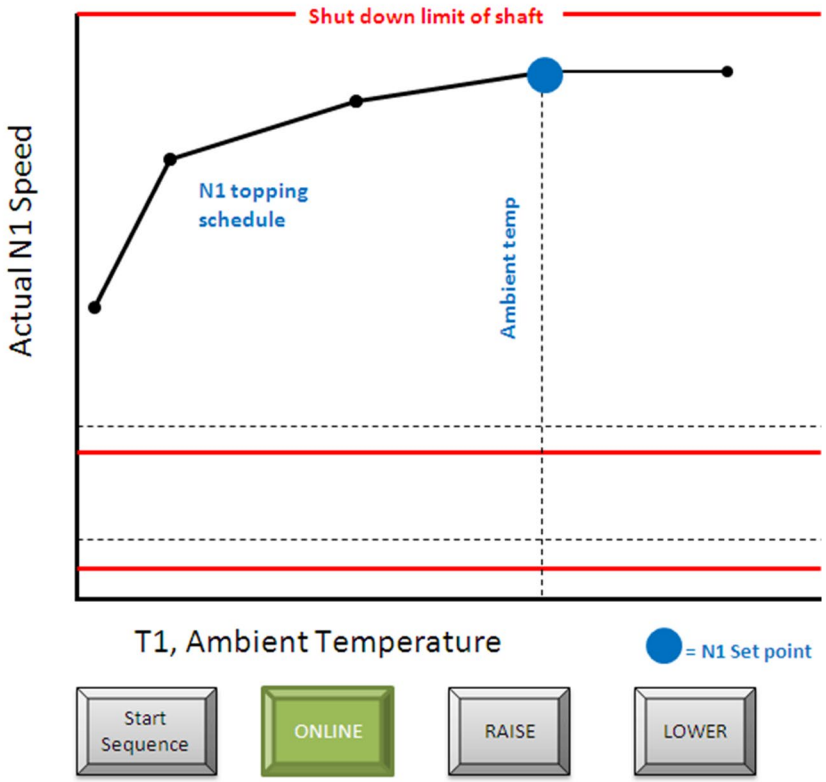
Governors – Start Fuel

- Controls fuel flow to the engine during starting
  - FGMP > CDP
  - Ignitors ON, establish flame
  - Sufficient net accel torque
  - Starter cut, lit GT assistance vs unlit GT resistance
  - Stable flame/aerodynamics to idle
  - Acceptable EGT, speed rise, prevent overfuelling
- Fuel flow is strictly controlled
  - PID control not used
- Starter, ignitors and lube oil are controlled via Package Control



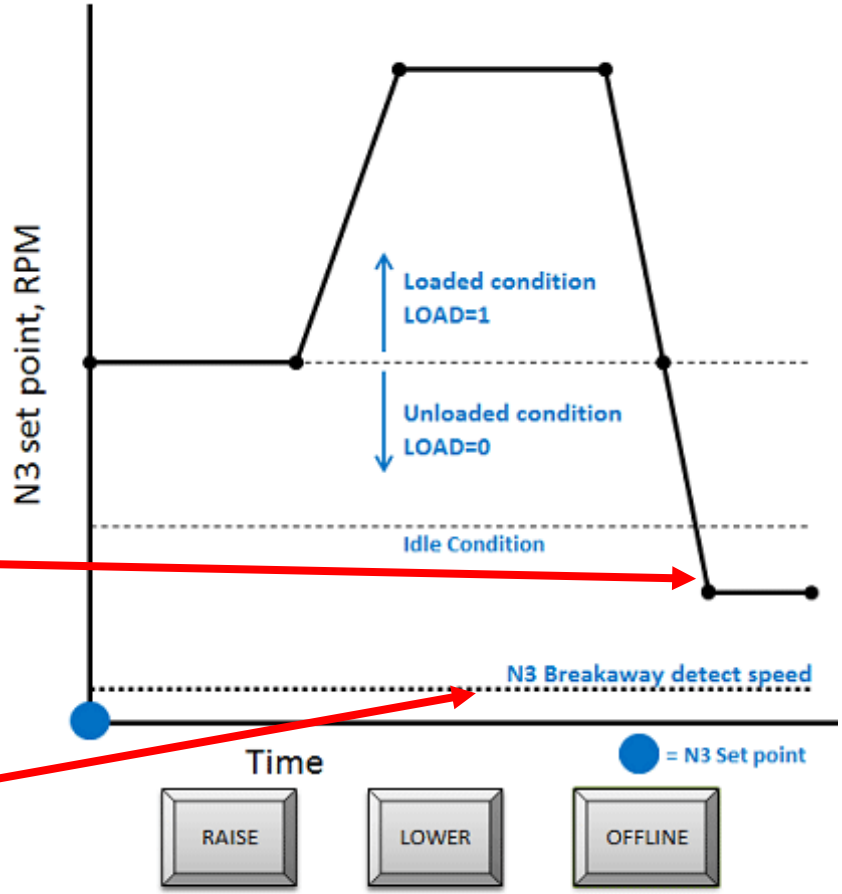
Governors – Core Speed Control

- N1 Controller
  - Ensures max N1 not exceeded for a given ambient temp
  - “Ambient Biasing” schedule, as T1 decreases so does N1
  - Lower T1, more air mass flow with less speed
  - Protect max rating of driven equipment or the engine
- N1B bottom controller
  - For unloaded & loaded
  - Ensures that the speed does not fall below the minimum allowable
  - Prevents underspeed and flameout



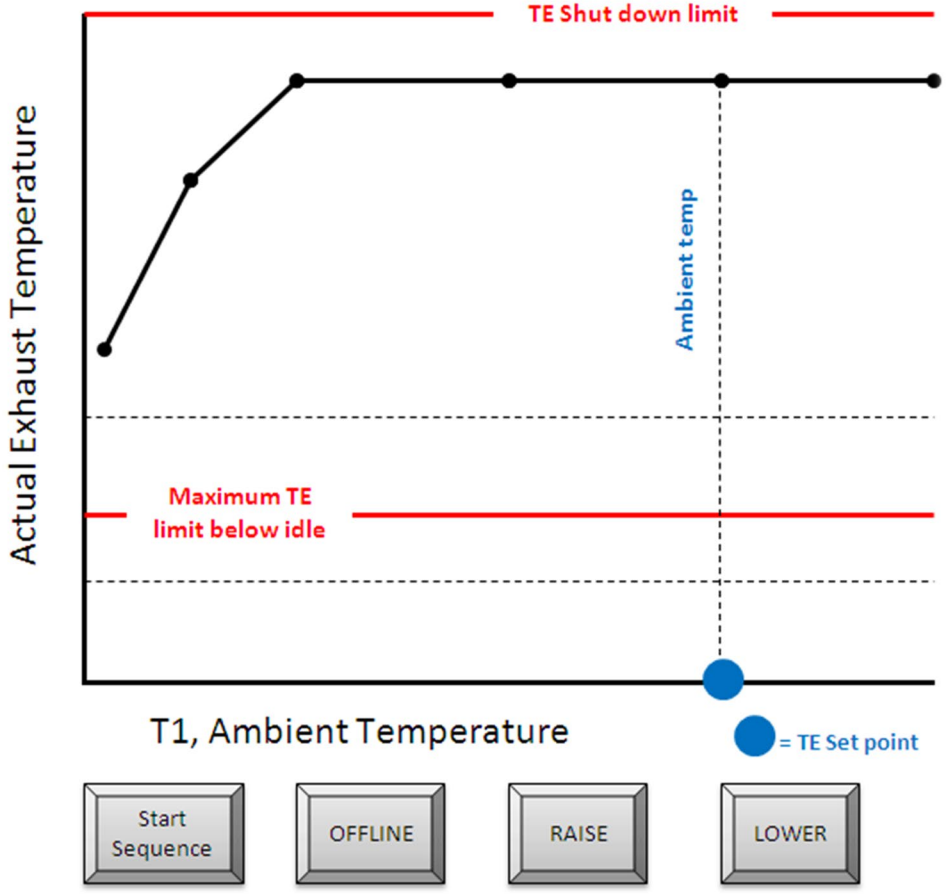
Governors – N3 (PT) Control

- N3 Controller
  - Controls N3 speed to the desired setpoint
  - Raise/Lower commands vary setpoint
- N3 bottom speed controller
  - Ensures PT speed does not fall below the minimum allowable
  - Prevents PT underspeed
- N3 breakaway control
  - initiated if PT has not started rotating



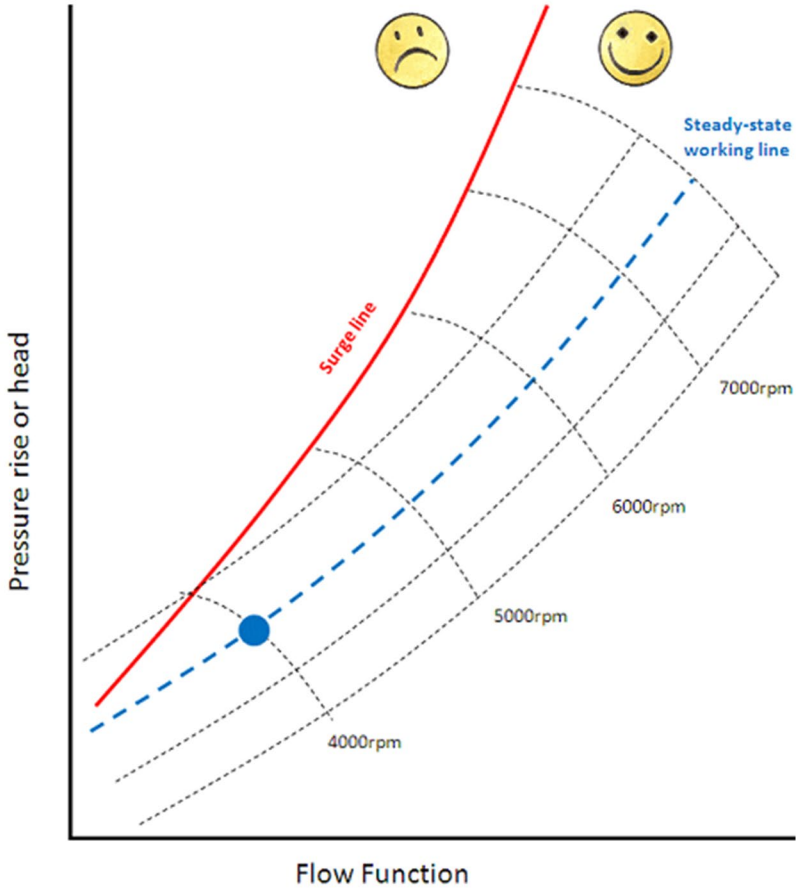
Governors – Exhaust Temperature Control

- This controller has two purposes:
  - Limit EGT to maintain the hot gas path components
  - On colder days backup to the N1 ambient biasing to limit output power
  - On hotter days it is usually the limiting schedule
- Typically, different trip limits for start sequence and above idle



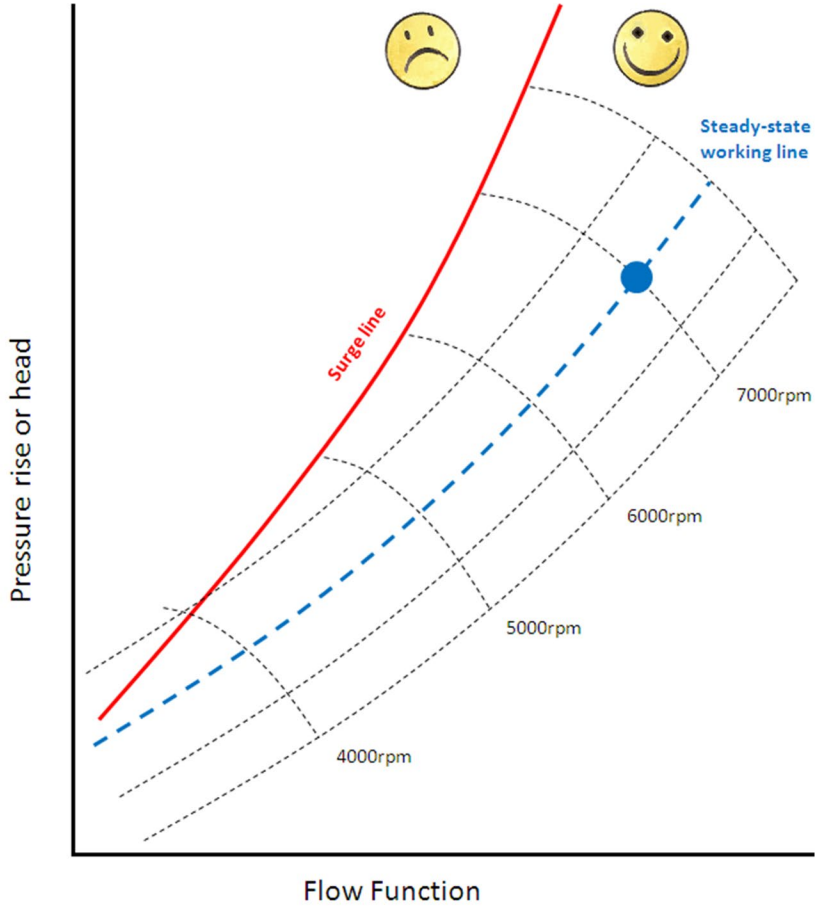
Governors – Acceleration Control

- Accel limit should not normally occur on a pipeline application
- Prevents over-fuelling the gas turbine during fast load acceptance
  - Protects hot gas path components
  - Over-speed/temperature
  - Potential HP comp surge
- Various methods of control
  - the fuel valve is not allowed to open more than allowed by the Accel Schedule.



Governors – Deceleration Control

- Prevents under-fuelling the turbine during fast load rejection
  - Protects against flameout
  - Potential LP comp surge
- For normal operation, the gas turbine should not hit the decel limit
- Various control methods
  - Manifold Pressure is used to estimate fuel flow vs valve position
  - Preventing valve from closed too much



Governors – Miscellaneous

- Maximum & minimum fuel limiters
  - Act as a min/max clamps on the fuel valve demand.
  - Act as a backup to other controllers , i.e. max limiter backs up the Acceleration controller to prevent over-fuelling during fast load acceptance
- CDP pressure controller
  - Usually a backup controller, although in cold ambients can come into play
  - Ambient schedule, for any given TAMB calculates the max allowable CDP
- Stall Detection
  - Monitor CDP rate-of-change and magnitude
  - Detect and shutdown, not designed to try and recover

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