Flexibility Enhancements for Gas Turbines

FAST START PROGRAM

7/11/2016

Situation

- Renewable Energy installed capacity is still increasing – currently >13% of US total installed capacity.
- Wind and Solar with their characteristic fast changing output profiles, account for >80GWe in the US.
- Gas Turbine Plants are being challenged to provide the necessary fast response to maintain grid stability.

Definitions

- The DOE defines fleet flexibility as:
  - The ability of the generation fleet to change its output (ramp) rapidly, start and stop with short notice, and achieve a low minimum turn-down level.
- Key classifications for Peaking Plants:
  - Non-Spinning Reserve… Generation and responsive load that is off-line but can be fully responsive within 30 minutes.
  - Supplemental Reserve… Generation and responsive load that is off-line but can be fully responsive within 10 minutes.

Topics

- Advance Class vs Legacy Fast Start
- Quantify Start Up Times – do you need to do anything?
- What options do we have to increase Flexibility?
- What are the O&M impacts?

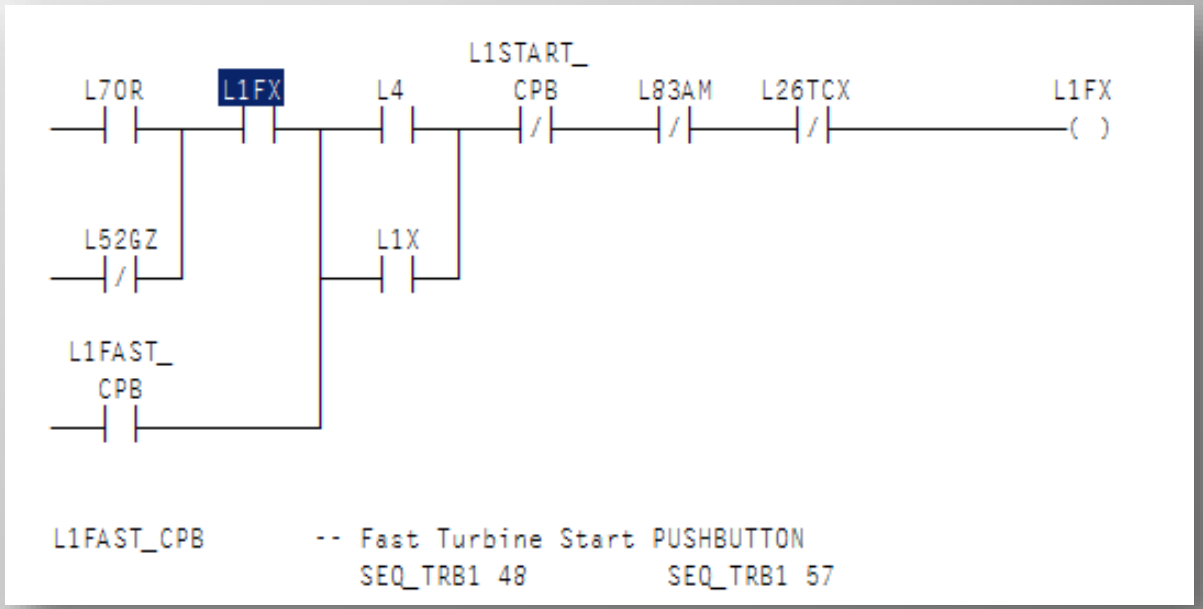
Legacy vs Advanced Class Flexibility

Legacy Unit Traditional Fast Start

- Reduce Diesel Warm Up Timer
- Reduce Turbine Warm Up Timer (F5P only)
- Fast Sync (ΔV ignored)
- Increased Acceleration Rate
- Increase Loading Rate

Enhanced “F” Class Flexibility

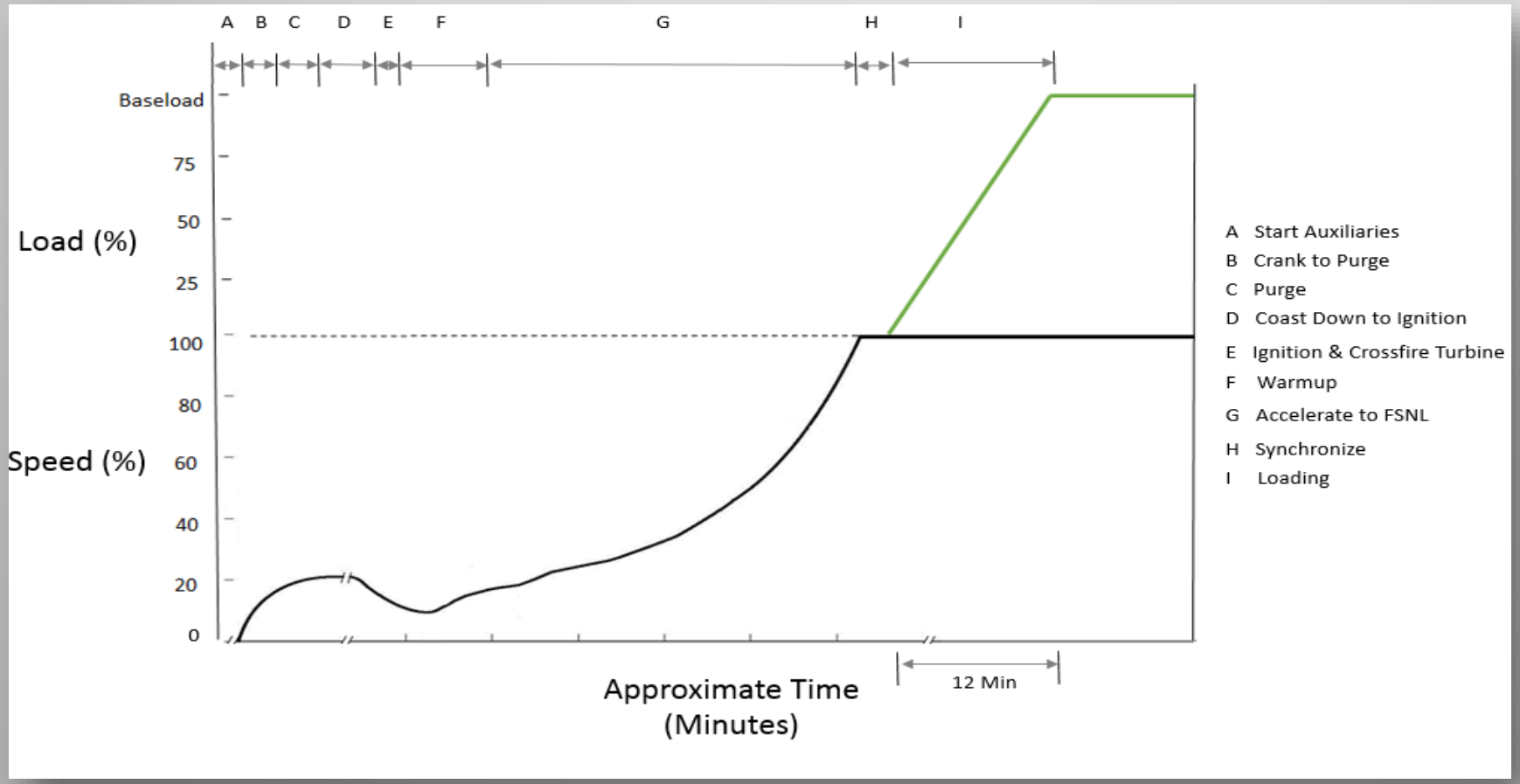
- Get Purge Credit
- LCI Pre-connect
- Ignition During Acceleration (Fire on the Fly)
- Eliminate Warm Up
- Fast Sync (ΔV ignored)
- Increased Acceleration Rate
- Increase Loading Rate



Start Up Times & Loading Rates (<10 Highlighted)

Turbine Starting Time						Loading Rate		Time To Base Load	
Gas Turbine	Starting Device	Type Of Start	Diesel Warm-Up	Turbine Starting Time	Time To FSNL	Non-DLN	DLN	Non-DLN	DLN
MS5001P	Diesel	Normal	2.00	7.17	9.17	4.00	4.00	13.17	13.17
		Fast Load	0.50	7.17	7.67	0.50	2.00	8.17	9.67
MS6001B	Diesel	Normal	2.00	10.00	12.00	4.00	4.00	16.00	16.00
		Fast Load	0.50	6.67	7.17	0.50	2.00	7.67	9.17
MS7001EA	Motor	Normal	0.00	7.50	7.50	12.00	12.00	19.50	19.50
		Fast Load	0.00	7.50	7.50	1.50	3.00	9.00	10.50
W251 B11/12	Motor	Normal	0.00	14.66	14.66	20.00		34.66	
		Fast Load	0.00	14.66	14.66	8.00		22.66	
W501D5	Motor	Normal	0.00	20.00	20.00	30.00		50.00	
		Fast Load	0.00	20.00	20.00	20.00		40.00	

Typical Start Up Curve for GE F7EA



Components of a Startup

Phase

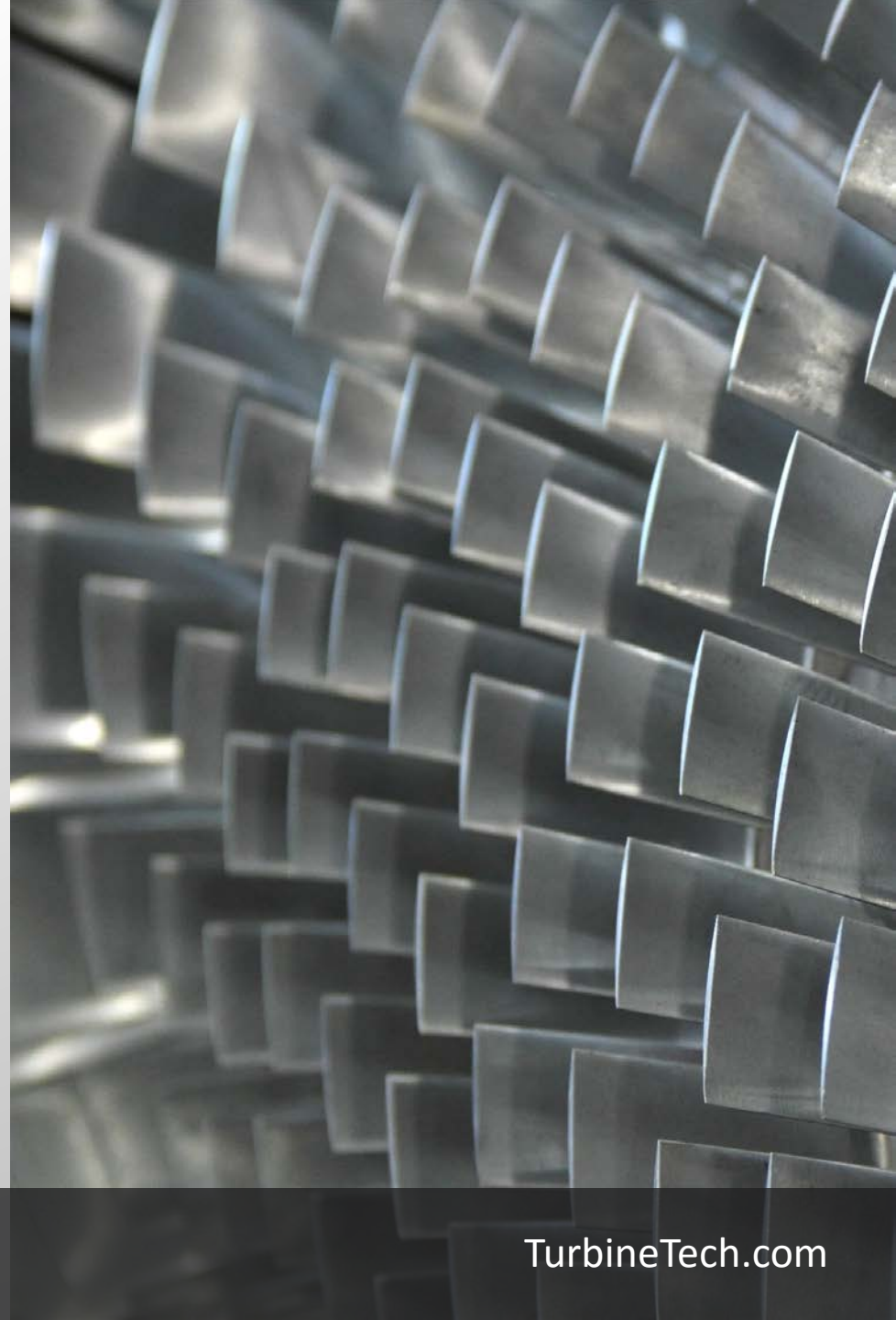
A. Start Auxiliaries
B. Crank to Purge
C. Purge
D. Coast Down to Ignition
E. Ignition & Crossfire
F. Turbine Warm-Up
G. Accelerate to FSNL
H. Synchronize
I. Loading

Time Duration is a Function of:

A. Equipment Reliability – O&M
B. Starting Means installed – Diesel, Motor or LCI.
C. Exhaust design, NFPA requirements
D. Sequencing and inertia.
E. Sequencing.
F. Turbine design - constants within sequencing.
G. Turbine design - constants within sequencing.
H. Sync components and governor settings.
I. Turbine & Generator design - constants within sequencing.

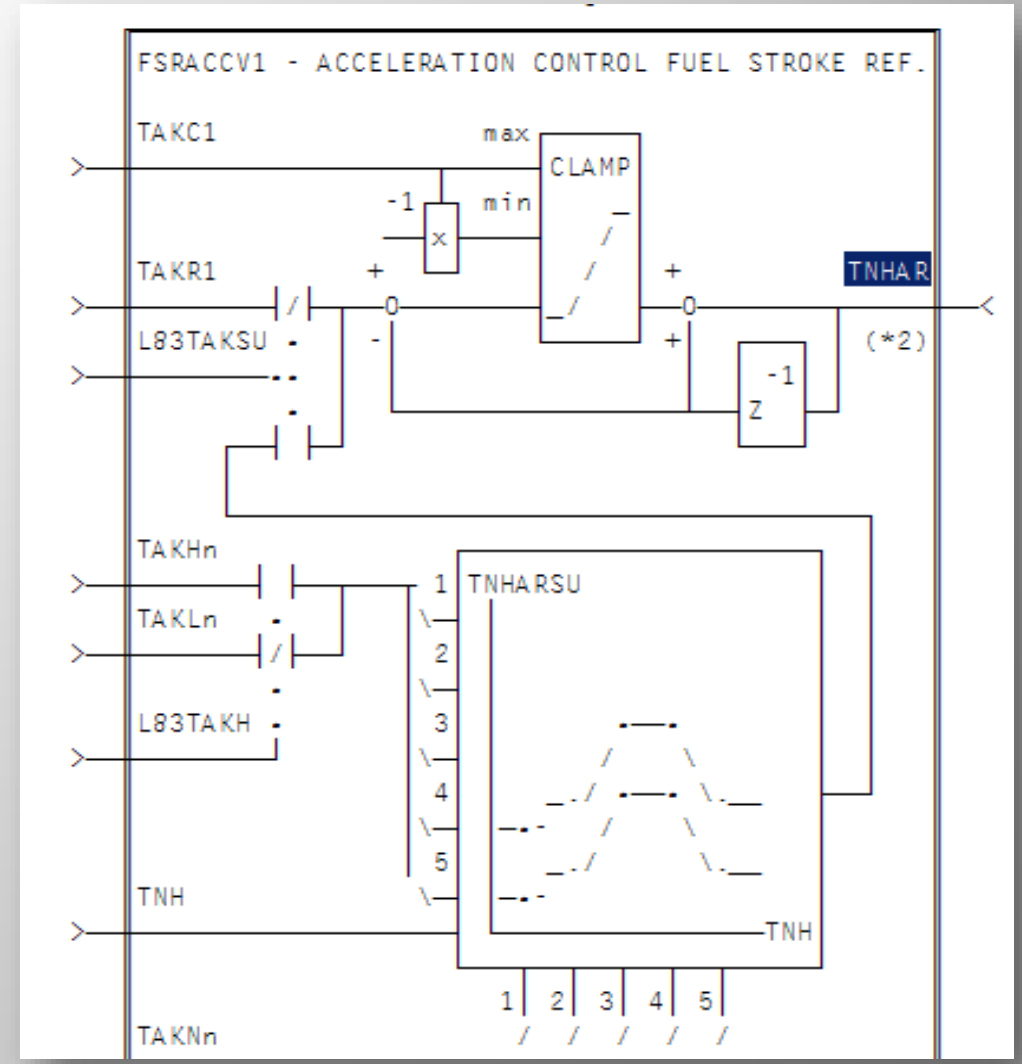
Increase Flexibility – Reduce Start Time

- Test & implement any existing Fast Start capability.
- Improve starting reliability.
- Establish Purge Credit if required.
- Implement techniques from Advanced Class units
  - o “Fire On The Fly”
  - o Fast Sync



Existing Fast Start

- Review Control Specification, Sequencing and HMI Application
  - Is Fast Start implemented, is it enabled, can you select it?
- What does it do?
  - Check constants for warm up timers, acceleration and loading rates.
- Test Fast Start the unit and record the start time.
- Modify, correct as necessary.
- Implementing the existing Fast Start will have a negative impact on Maintenance Factors, this impact must be considered.



Improve Starting Reliability

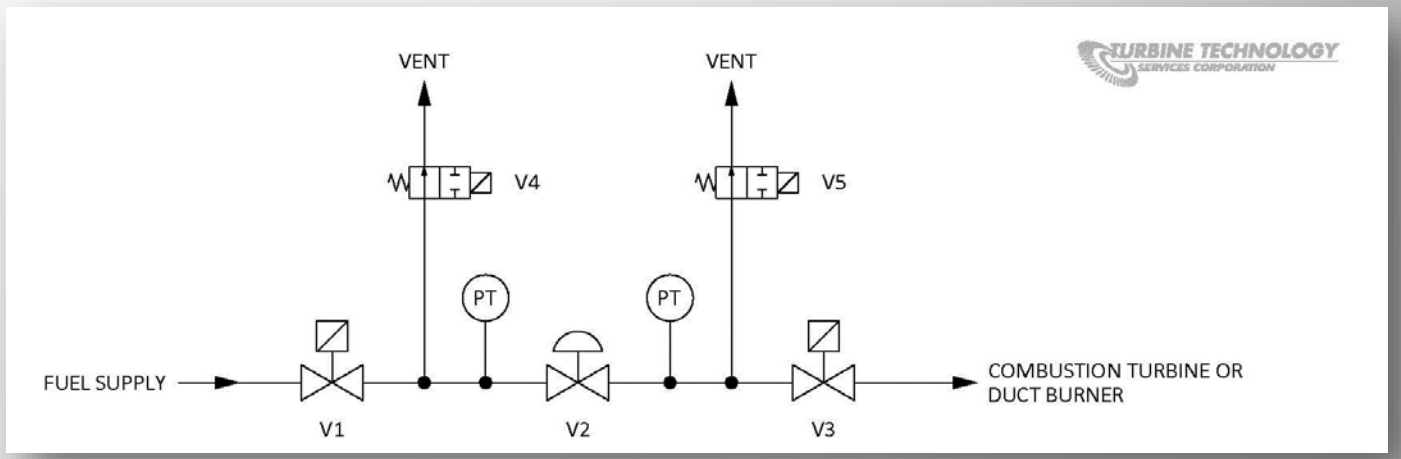
- O&M Practices
  - Fuel System Calibration
  - Device Calibration
  - System Testing
- System Modifications
  - SSS Clutch – a common issue is misalignment of the jaw clutch and 33CS not being set properly, this can be resolved through proper alignment checks or simply installing a SSS clutch for increased reliability.

Purge Credit

- NFPA® 85 2015 8.8.4.6 (Gas) and 8.8.4.7 (Liquid) allow for a Combustion Turbine Purge Credit
- In simple terms, after a normal stop, the unit is purged and this purge counted as the purge for the next start, resulting in significant start up time savings.
- There are specific requirements detailed in NFPA® 85 2015 that must be adhered to in order to establish and maintain the Purge Credit.

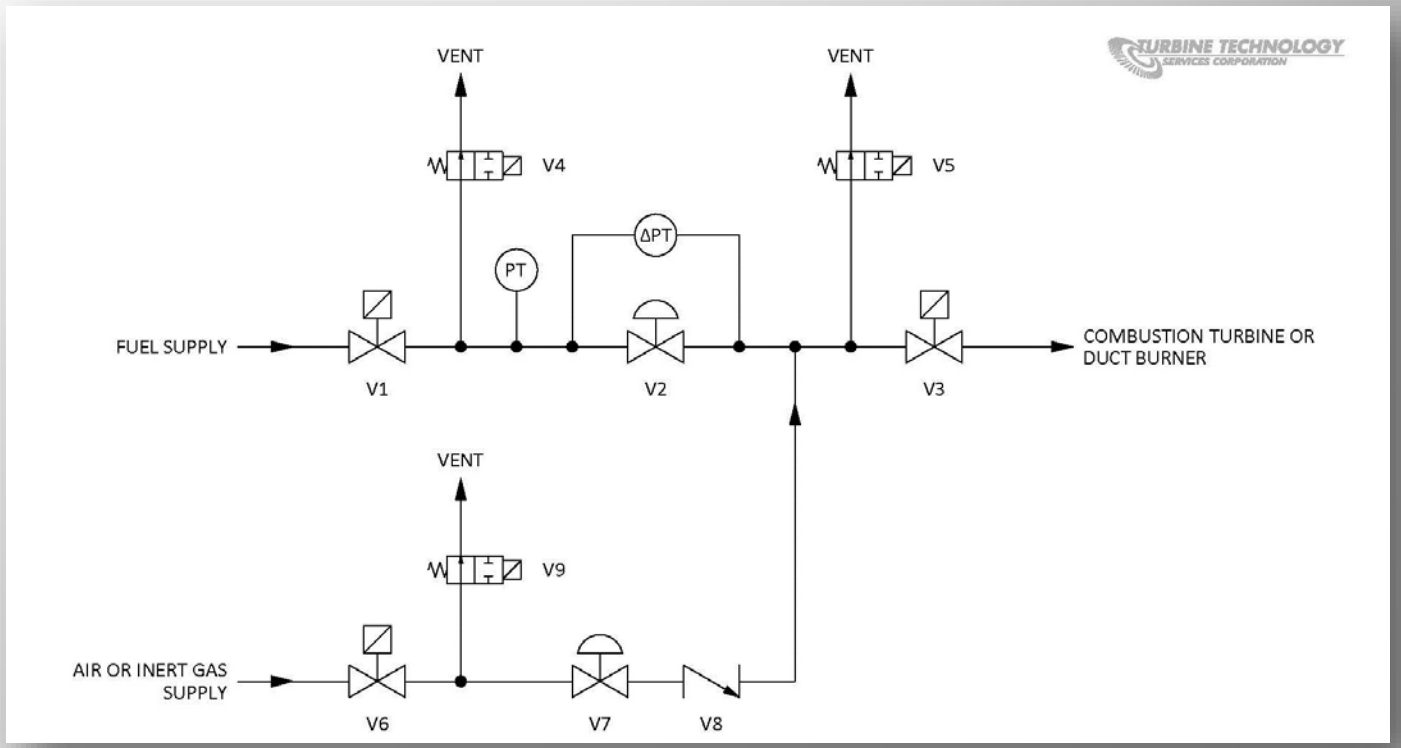
NFPA® 85 2015 8.8.4.6 (A) Valve Proving Method

- Normal Shutdown
- Valve Positions Continuously Monitored
- Inter-valve Pressures Continuously Monitored
- On shutdown and startup, block valves are validated for gas leak tightness via a valve proving system.
- Credit is for a maximum of 8 days, can be renewed.
- If any monitoring or testing fails then purge credit is lost.



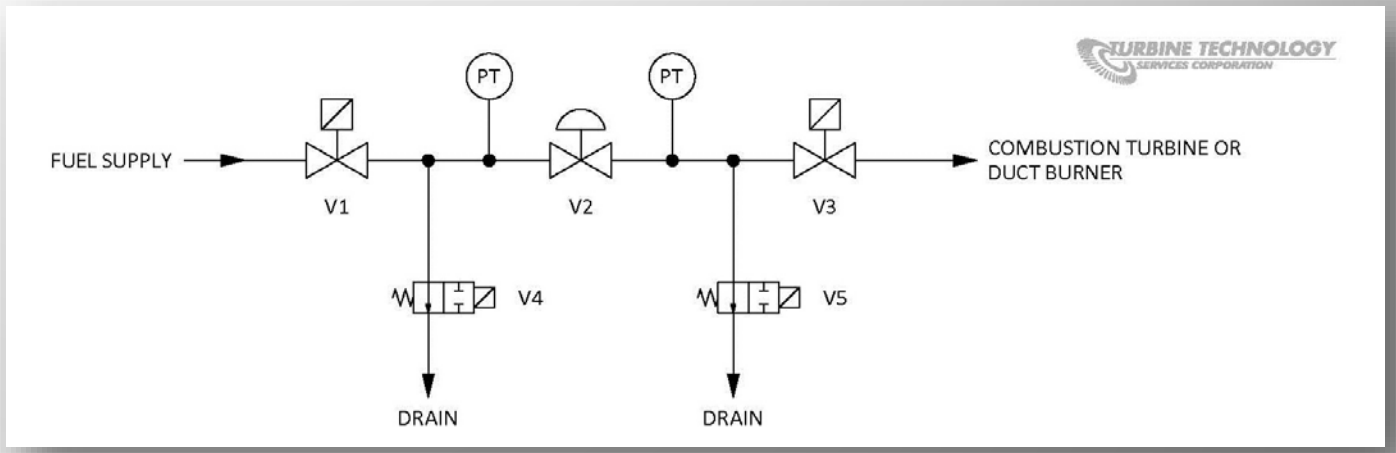
NFPA® 85 2015 8.8.4.6 (B) Pressurized Pipe Section Method

- Normal Shutdown
- Air or Inert Gas used to pressurize inert-valve.
- Valve positions continuously monitored.
- V2 ΔP > 3psid continuously monitored.
- On shutdown and startup, block valves are tested.
- Credit is unlimited as long as conditions are met.
- Ensure fuel gas cannot enter air or inert gas supply line – check valve.
- Any monitoring or test fails then purge credit is lost



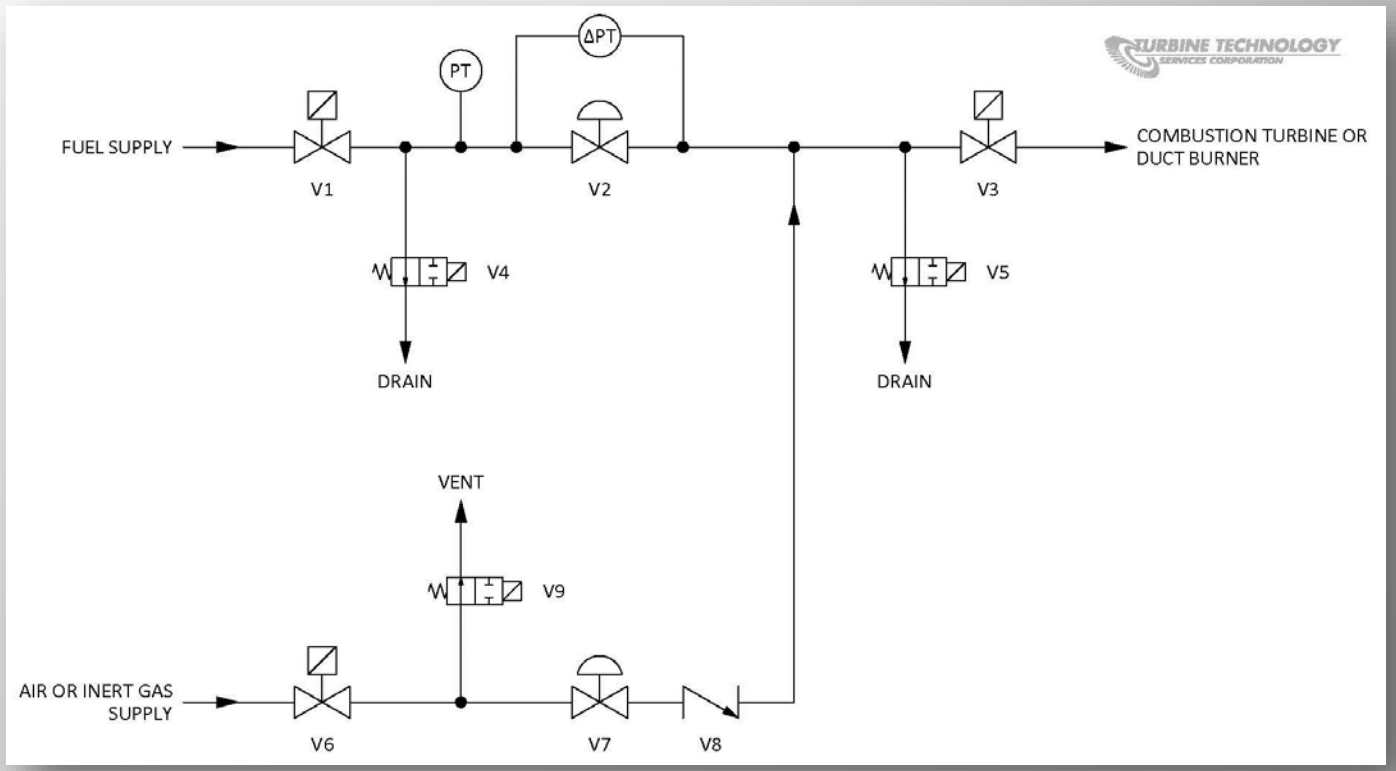
NFPA® 85 2015 8.8.4.7 (A) Proof-of-Closure Method

- Normal Shutdown
- Valve positions continuously monitored
- Inter-valve pressures continuously monitored
- On shutdown and startup, block valves are validated for fuel leak tightness via a valve proving system.
- Credit is for a maximum of 8 days, can be renewed.
- If any monitoring or testing fails then purge credit is lost.



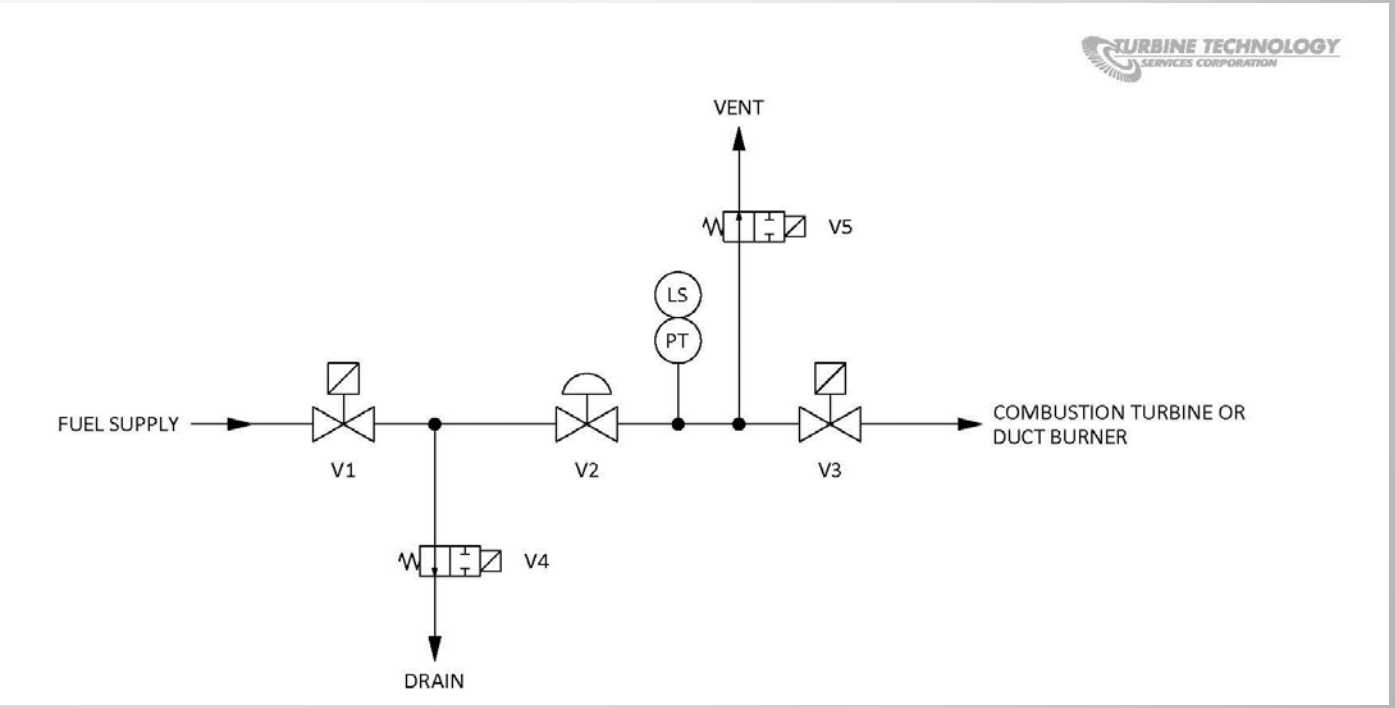
NFPA® 85 2015 8.8.4.7 (B) Pressurized Pipe Section Method

- Normal Shutdown
- Air or Inert Gas used to pressurize inert-valve.
- Valve positions continuously monitored.
- V2 ΔP > 3psid continuously monitored.
- On shutdown and startup, block valves are tested.
- Credit is unlimited as long as conditions are met.
- Ensure fuel gas cannot enter air or inert gas supply line – check valve.
- Any monitoring or test fails then purge credit is lost



NFPA® 85 2015 8.8.4.7 (C) Liquid Level Monitoring Method

- Normal Shutdown
- Addition of vertical pipe section with vent.
- Valve positions continuously monitored.
- Liquid level continuously monitored.
- Credit is unlimited as long as conditions are met.
- Any monitoring or test fails then purge credit is lost



Implementing Purge Credit

Typical Gas Fuel Valve –
Frame 7 Y&F Series 7500

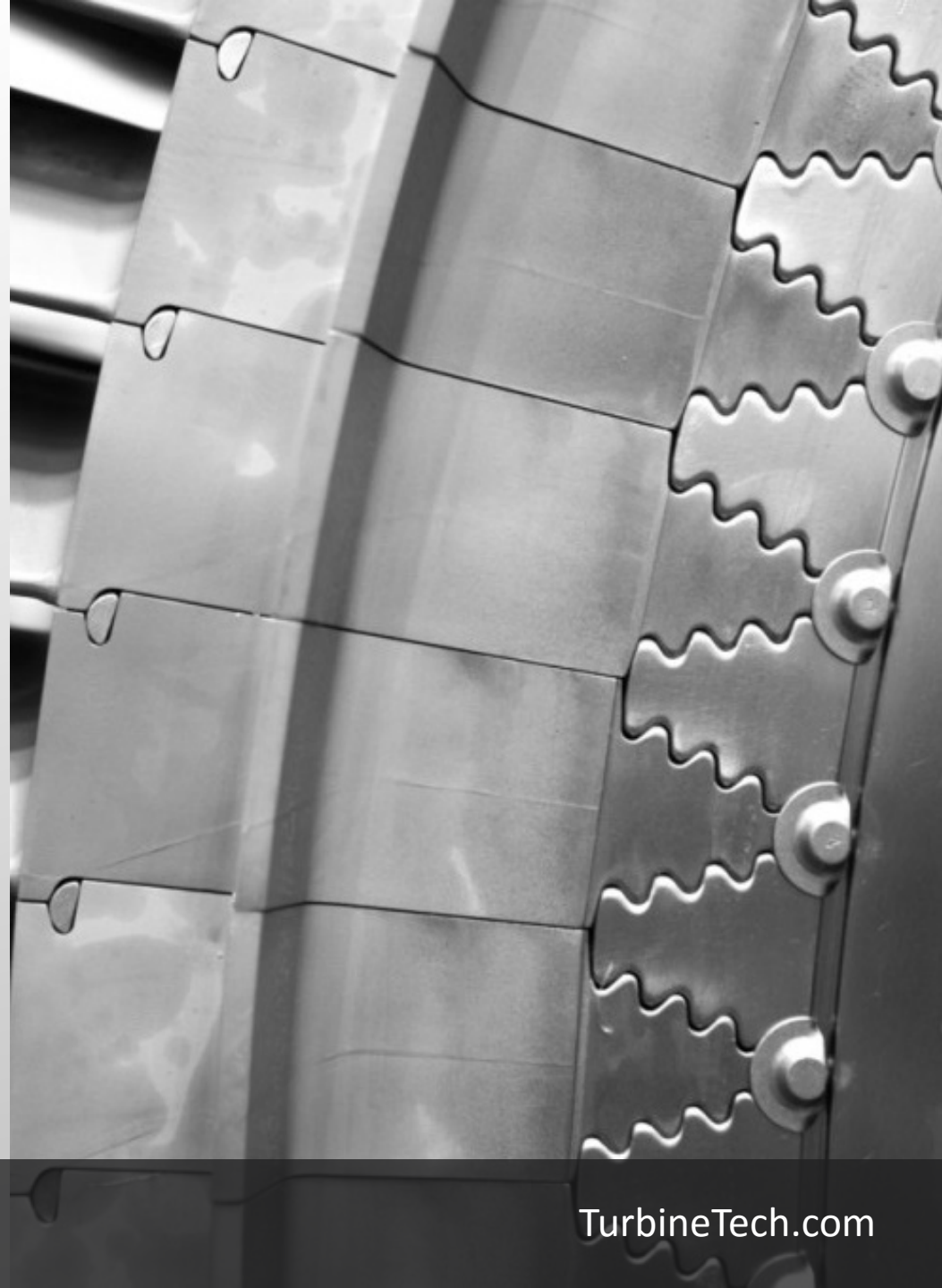
Typical Gas Fuel Valve –
Frame 6 Y&F Series 9500

Fuel delivery system design is key to obtaining a Purge Credit and achieving Fast Start compliance. TTS' Fast Start Program offerings include:

- Redesign of fuel delivery system to meet the NFPA standards with Purge Credit.
- Implementation of the necessary control system changes to support the fuel system upgrade.
- Consulting with clients to provide them with the best strategies to achieve fast start on their machines.

Implementing Purge Credit

- Fuel System
  - Triple Block & Bleed will be necessary.
  - Latest valve options include hydraulic and electric actuation.
- Controls
  - Implementation of control algorithms for new valves – electric actuation.
  - Implementation of control algorithms for method chosen – for example Valve Proving.
- O&M Considerations
  - Initial expenditure for new valves, piping, instrumentation and controls modifications.
  - Ongoing device calibration and valve maintenance for additional devices.
  - No impact on Gas Turbine or Generator Maintenance Factor.

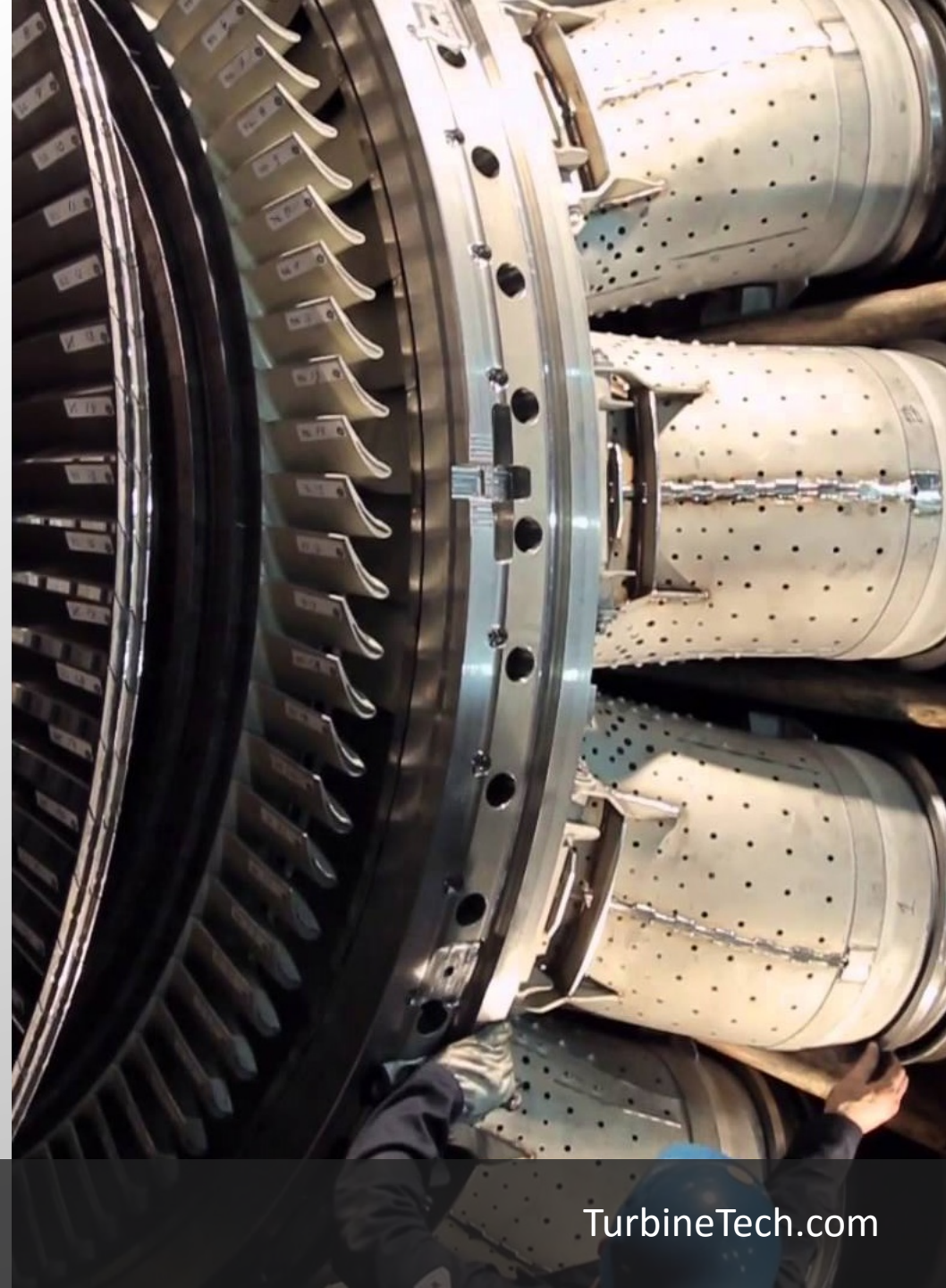


Fire on the Fly

- There are two components to Fire on the Fly
  - Initiating Fire while accelerating the Gas Turbine
  - Removal of the Warm-Up period.
- This can be easily implemented through sequencing changes alone.
- Implementing Fire on the Fly will have a negative impact on Maintenance Factors, this impact must be considered.

Summary

- Flexibility – Fast Start already exists in some form or other for Legacy Peaking Units.
- There are options to improve this Flexibility
  - Major – Purge Credit through Fuel System redesign.
  - Minor – Sequencing changes
  - Routine – adherence to good O&M practices on the critical starting components.
- In all cases close reference to GER-3620M Heavy-Duty Gas Turbine Operating and Maintenance Considerations is strongly advised.



We know gas turbines.

FAST START PROGRAM