

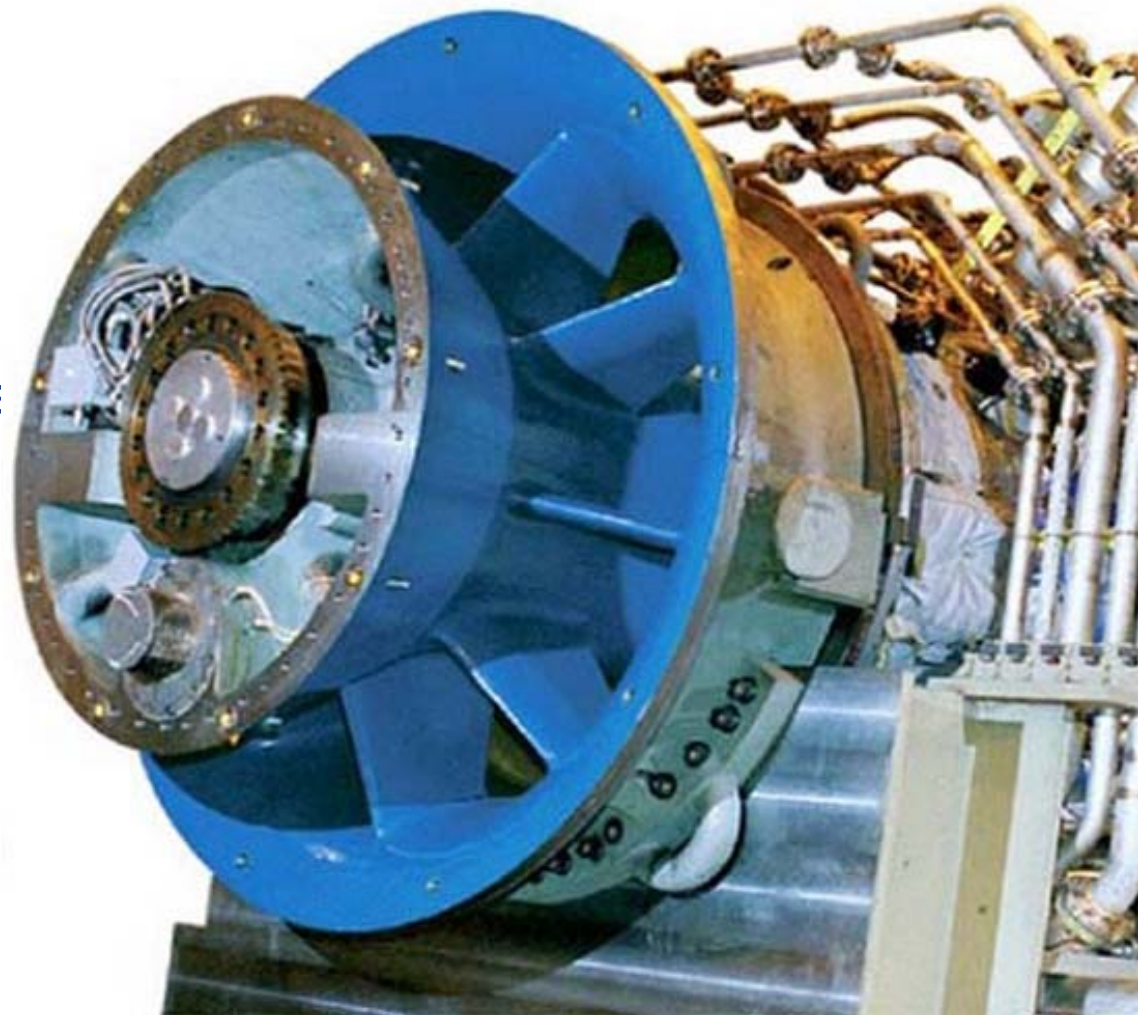
# GE Energy

## Rapid Response Combined Cycle

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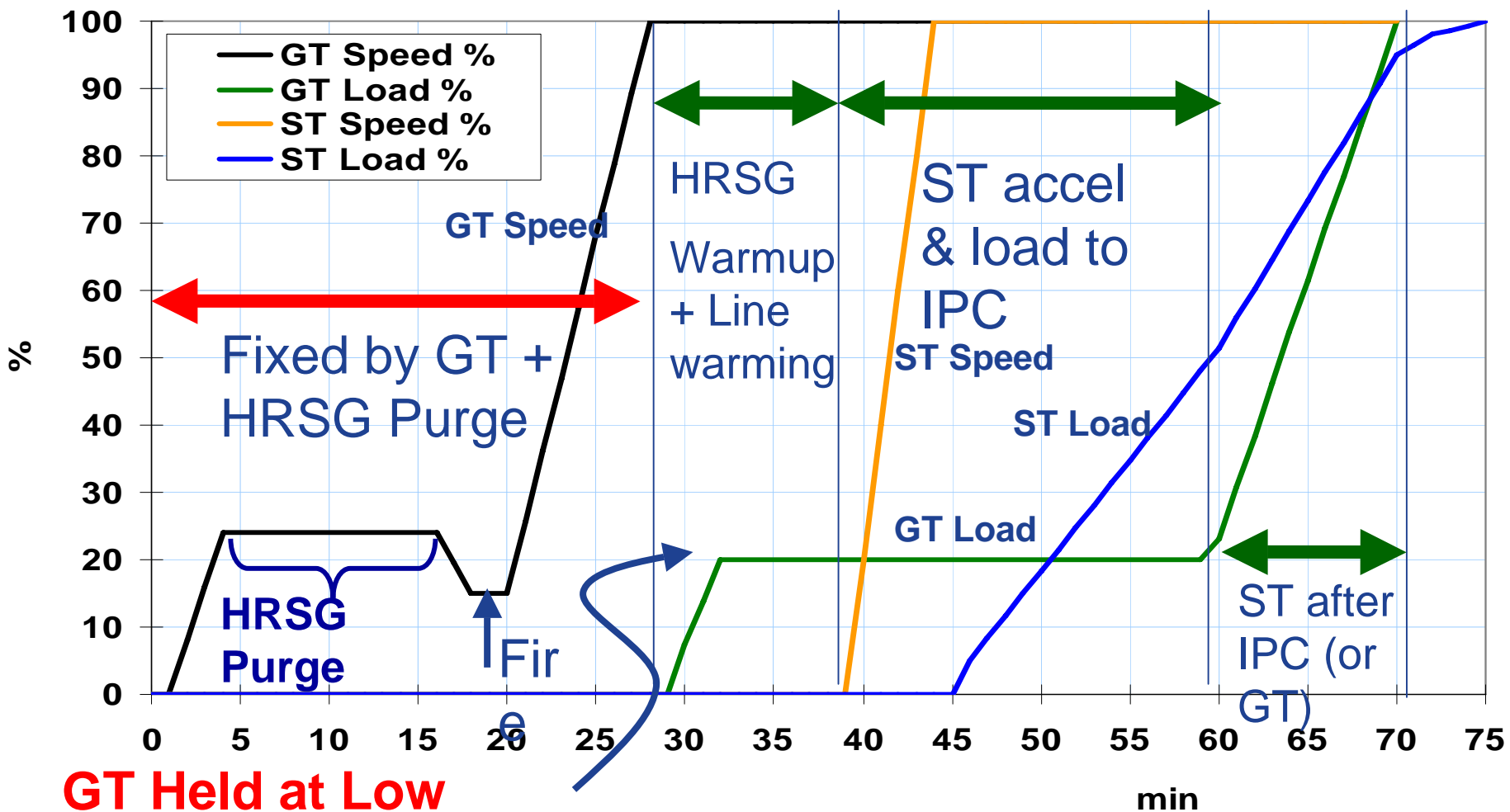
# Combined Cycle Startup Emissions

Conventional CC Start Method

Impact on Startup Emissions

# Conventional CC System Start Method

## Example Combined Cycle Hotstart

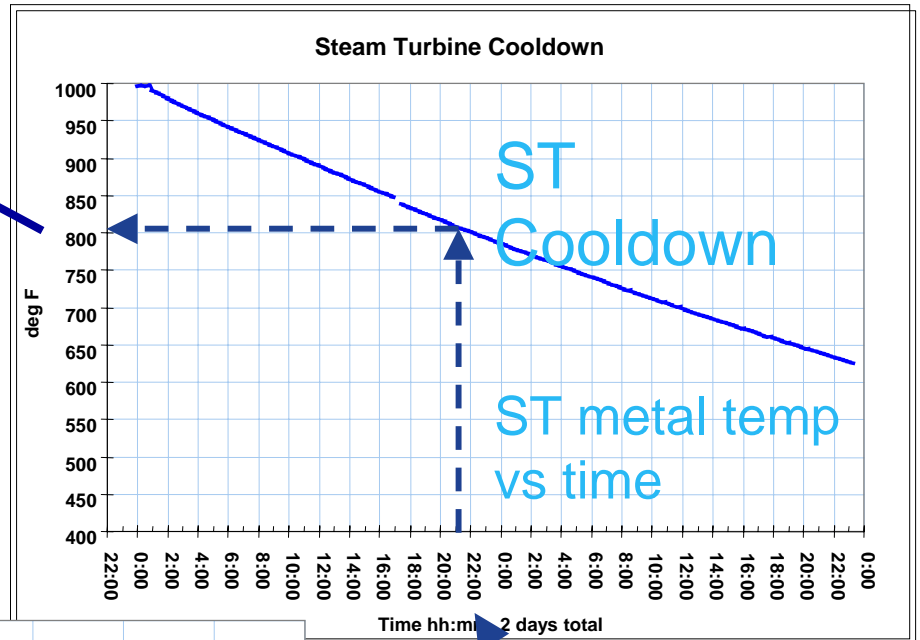


**GT Held at Low Load**

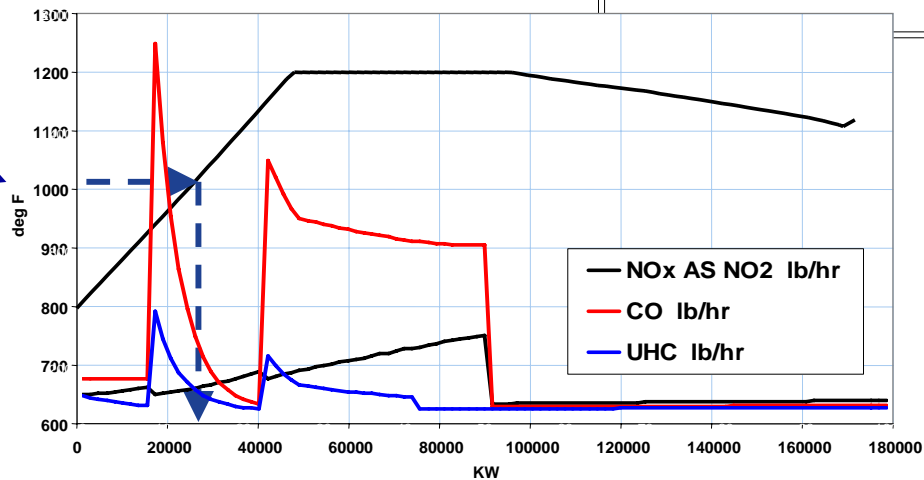
# What Sets the GT Load Hold Level ?

## ST "Temp Match" Criteria

$$700F < T_{\text{metal}} + \text{bias} < 1050F$$



GT Tx vs Load



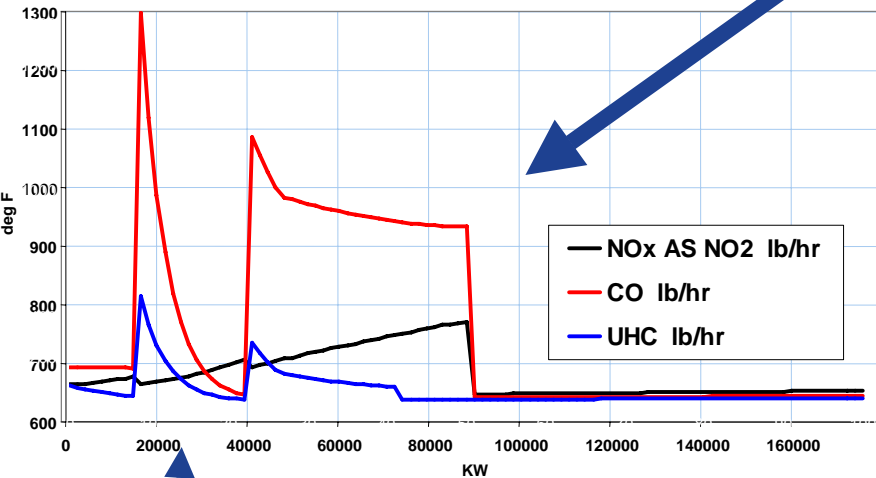
Time of Start,  
Previous Hours  
of Shutdown

**GT Load Hold Level Determined by ST Initial Temp**

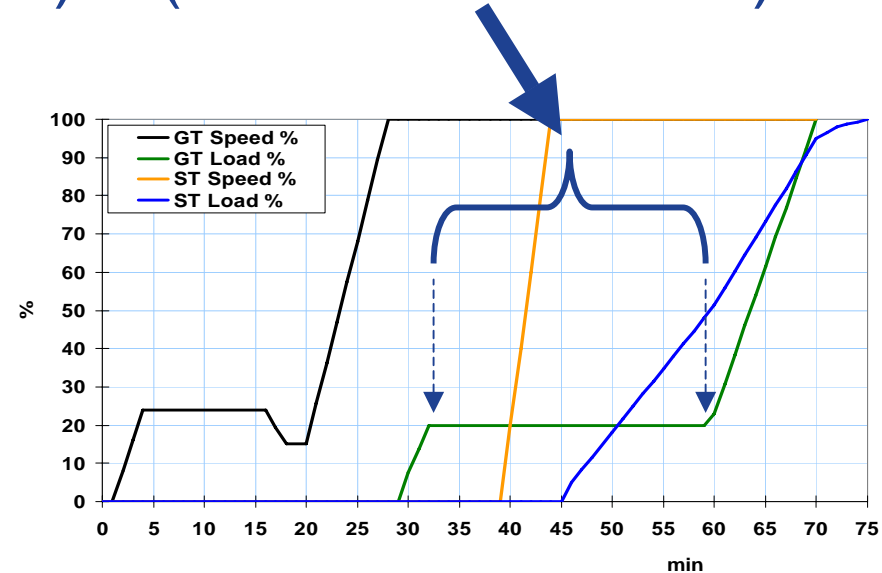
# Uncertainty in Start Emissions Estimates

Per Start, Total Emissions in lbs =  
 (Rate in lb/hr) x (Duration in hours)

GT Tx vs Load



GT Load Level  
 drives Emissions  
 Rate



Plant Design & Operation  
 drives hold duration (steam  
 line warming, ST loading, etc.)

**Two Factors = Uncertainty in Startup Emissions  
 Estimates**

# Conventional CC Startup Emissions

- A function of the GT emissions vs load characteristic *and* GT startup sequence
- GT emissions vs load characteristic is highly discontinuous in region of load hold, small load change can cause large emissions change
- GT start sequence (low load hold) determined by plant design not just GT, often not under control of GT manufacturer
- Estimation of startup emissions in conventional combined cycle plants inherently has a large uncertainty

# GE Rapid Response CC Plant

Enabling Technology

Benefits & Costs

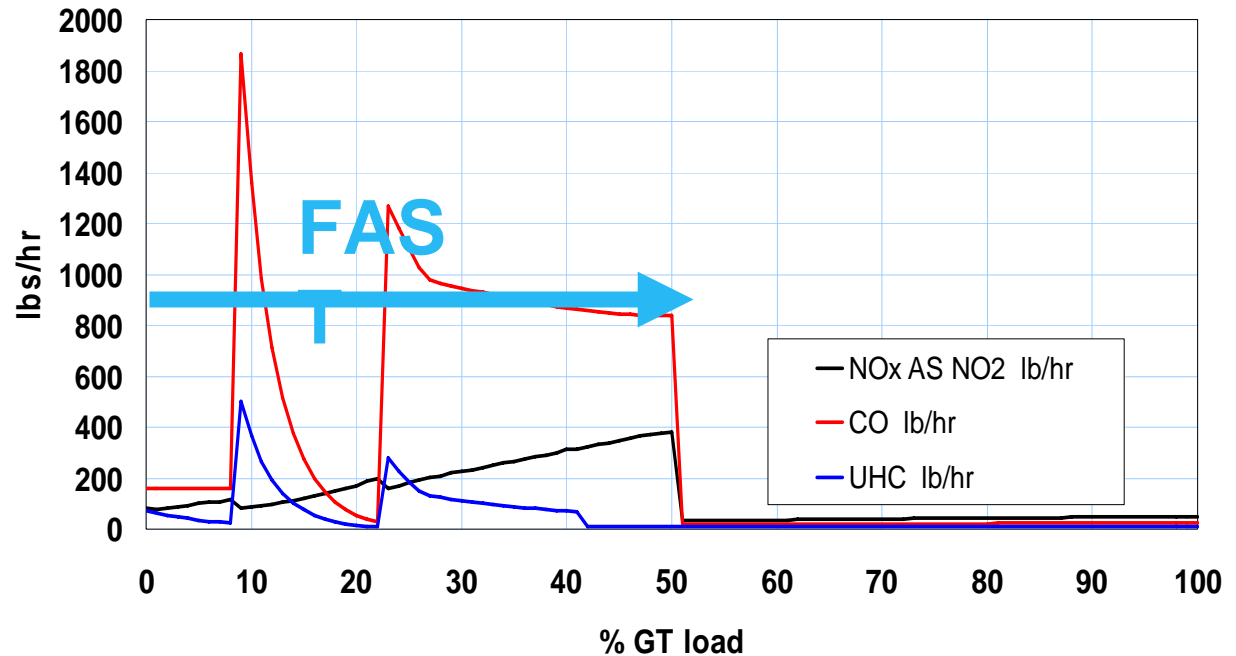
# Startup Emissions Optimization

DLN emissions vs load curve suggests optimal start characteristic

Move through low load / high emissions region as fast as possible

*As fast as possible* = GT simple cycle rate, rate of GT itself without any additional system based limitations

Typical DLN GT Emissions vs Load Characteristic



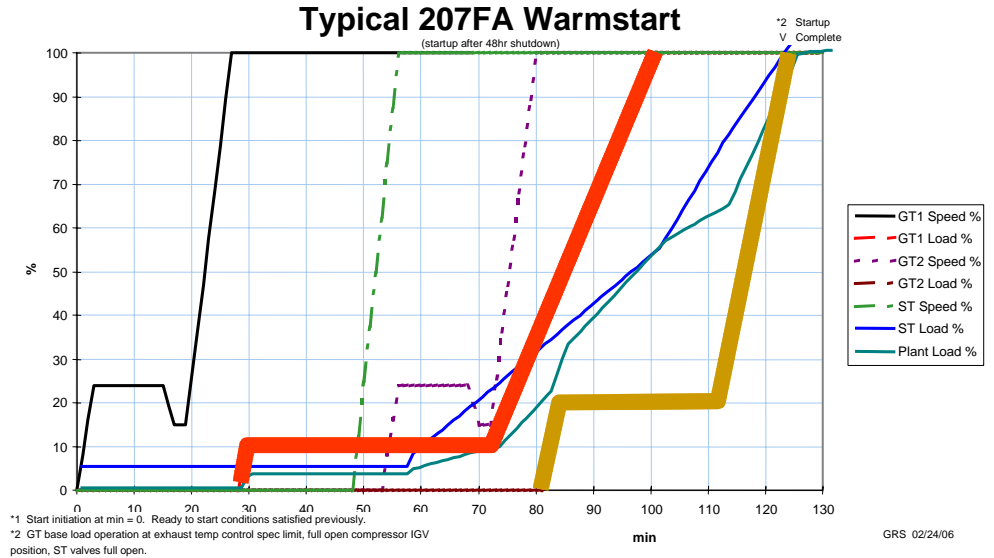
Start > GT Loading > End



# Rapid Response vs Conventional CC

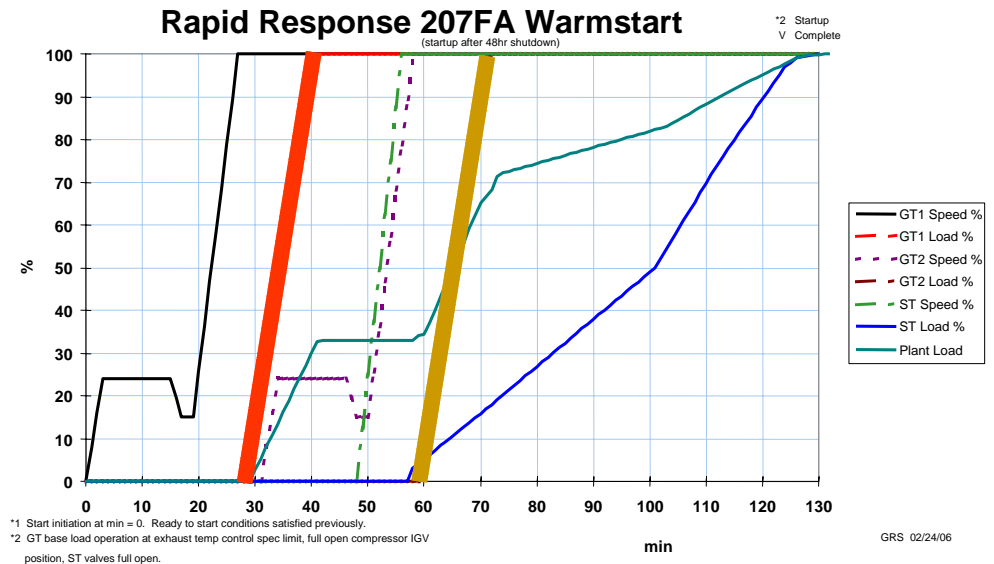
## Typical CC Start

- GT holds at low load
- Hold level and hold time both variable



## Rapid Response CC Start

- GT syncs and loads to base at simple cycle rate
- Short hold on coldest starts only, > 72 hours shutdown



# CC Startup New Technology & Evaluation

Conventional CC Plant not Optimized for cycling duty with frequent startups

GT holds at low loads

- HRSG warmup, traditional thermal stress mitigation
- Steam temperature matching for ST start
- Reheat pressure reduction for ST start, HP section
- GT fuel heating

Holds cause high emissions and low efficiency

Delay in MWs to the grid

Bottom line = Steam cycle limits GT startup

# CC Startup New Technology & Evaluation

GE **Rapid Response** CC System design breaks link between GT and steam cycle startup

Reasons for links have been “designed out”

- Drum type HRSG designed for 12 minute GT load ramp
- Additional steam attemperation capability
- Hybrid steam bypass system, ST start valve
- Startup GT fuel heating system, HRSG independent
- New control schemes

No change to plant base load performance or emissions

# CC Startup New Technology & Evaluation

## Extended scope basis

- The SYSTEM makes it work, not just GT & ST
- GE responsible for overall CC System design to achieve plant operability goals, fast start
- GE Supply Scope = Engineered Equipment Package, EEP
  - GT, ST, HRSG (life evaluated), DCS (new controls)
  - Key enabling BOP equipment by GE
    - Terminal attemperators
    - Hybrid steam bypass system
    - Condenser if water cooled
    - New startup fuel heater
    - ST HP exit startup valve
  - Key EPC Scope
    - Pipe warming evaluation / Steam warming line
    - Aux boiler to GE spec, fuel line routing per GE
    - Piping, electrical, civil, etc
    - GE approval of items impacting plant operability

# Rapid Response Emissions Benefits

*Red area is time between GT fire and GT emissions at guarantee level*

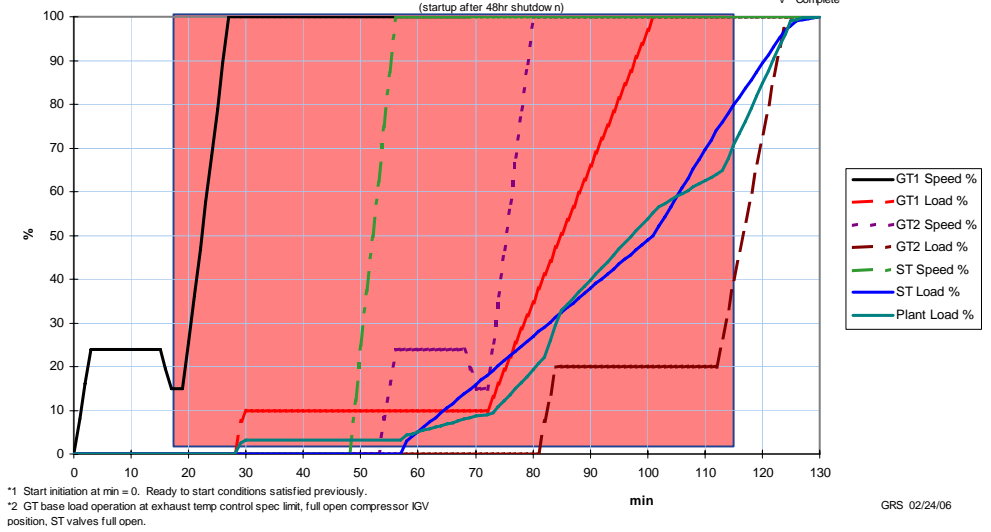
## Conventional CC Start

- Long time period
- Fire to approx 50% load

## Rapid Response CC Start

- Decreased time period
- Less uncertainty
- Reduced total startup emissions lbs

Typical 207FA Warmstart



Rapid Response 207FA Warmstart

