Startup time reduction for Combined Cycle Power Plants

8th International Gas Turbine Conference

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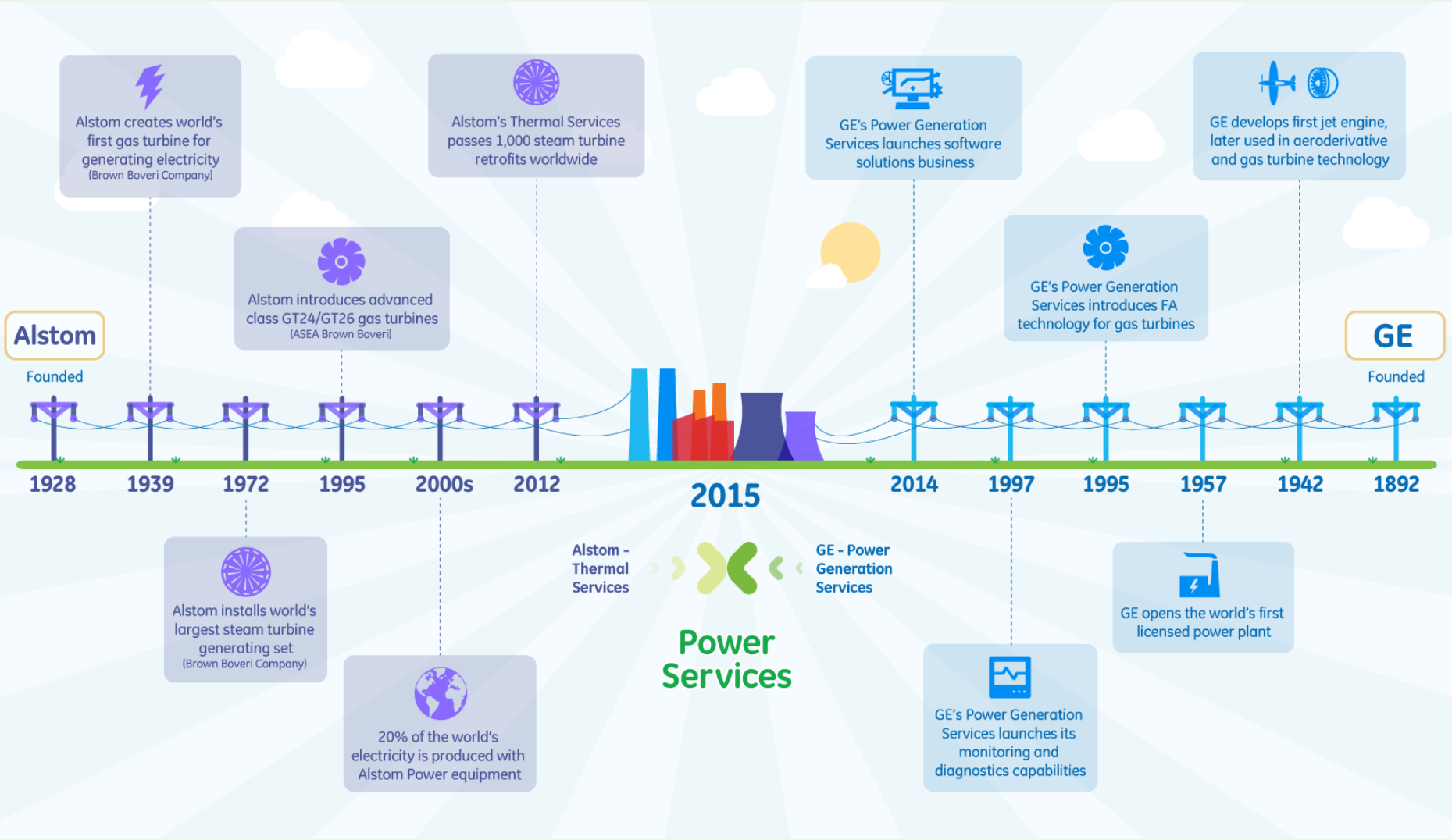
October 12, 2016

Imagination at work

We are better together: Our History



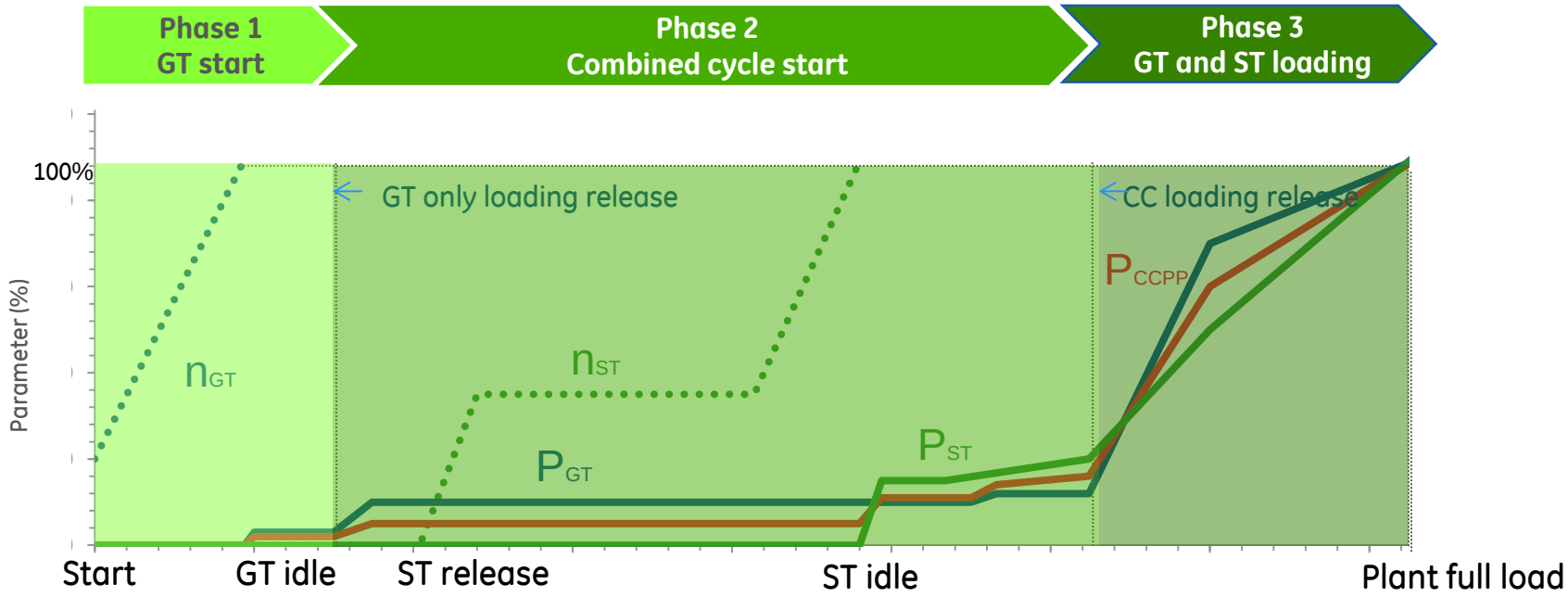
Operational flexibility

Increasing share of renewables leads to increased grid volatility

Fast back up can be achieved by Combined Cycle Power Plants:

- Non-spinning reserve: requires fast and/or more frequent start-ups
- Spinning reserve: operation on low part load to increase available load range

Typical cold start sequence



Phase 1:
- GT start and synchronisation
- Condenser evacuation
- Start of steam by-pass

Phase 2 :
- Water / steam chemistry
- ST run-up and synchronisation
- ST warm-up

Phase 3:
- Load increase based on allowable GT and ST gradients

Warm and hot start duration

Sample of approximate time (in minutes)	Phase 1	Phase 2	Phase 3
Cold	20-25	80	45
Warm	20-25	50	45
Hot	15-20	10	20-25

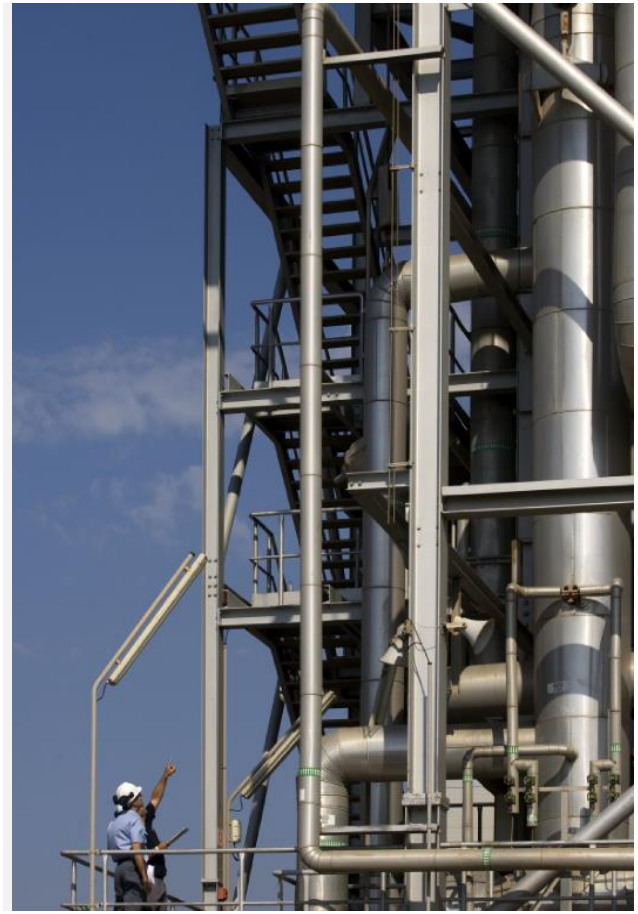
Warm starts:

- Phase 2 time is reduced because it is possible to warm-up the ST more quickly

Hot starts:

- Phase 2 almost completely eliminated because ST is still hot
- ST loading can be done with higher gradient

On which phase should be the main focus?



Depends on “type of start” that is most important for the expected operation profile:

- Cold start: phase 2
- Warm start: phase 2 and 3
- Hot start: phase 1 and 3

“Keeping warm” of HRSG and ST allows to move from one category in the next

Phase 1:
GT startup

Improvement potential during GT startup phase (phase 1)

Reduce time to GT start release:

- Maintain HRSG level (and pressure):
  - Keep HRSG warm
  - N2 capping
- Pre-sequencer

Purge credit

Improve condenser evacuation:

- Auxiliary steam to keep HRSG warm and to draw vacuum
- Vacuum ring pump

Keep HRSG warm

Short term:

- Stack damper
- Improve cold end insulation
- Reduce water losses

Longer term:

- Sparging steam in evaporator

Benefits:

- Reduces time to make steam available
- Reduces life consumption of pressure parts
- Less deposit loading

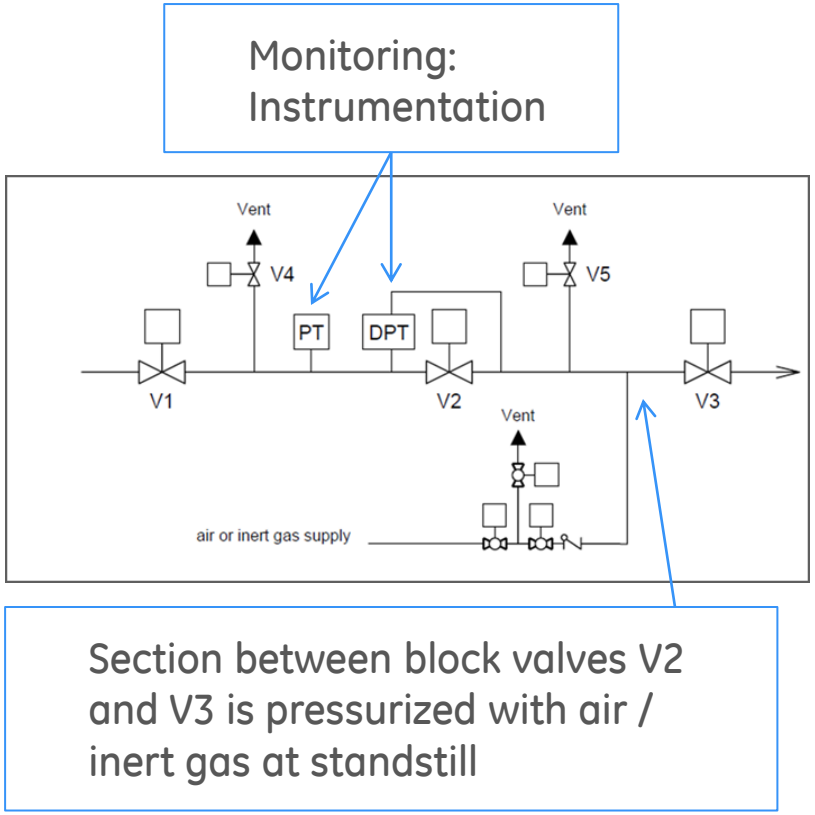
Purge credit (NFPA85)

Purge before light-off of GT:

- At least five volume changes
- Not less than 5 minutes

Purge during GT run-down (accepted since 2011):

- Normal engine run down
- Credit if unit can be kept in purged condition between restarts
- Solution for gaseous fuels: Triple block and bleed with pressurized pipe section



Time saving: 5 – 10 minutes
Preservation of energy and reduction of HRSG stress

Phase 2:
Combined cycle startup

Improvement potential during CCPP start-up phase (phase 2)

Pre-warming the steam turbine

Plant startup sequencer optimisation

Don’t wait for steam turbine warm up:

- Uncoupling water/steam cycle from gas cycle

Reduce waiting time for steam quality:

- Preservation to corrosion product loading:
  - Maintain pressure in HRSG:
    - Keep warm or nitrogen capping
  - Chemistry
- Improved sampling:
  - Degassed conductivity
  - Upgrade of sampling system

Uncoupling steam turbine from gas cycle

Loading of the GT to a high load without waiting time for the steam cycle

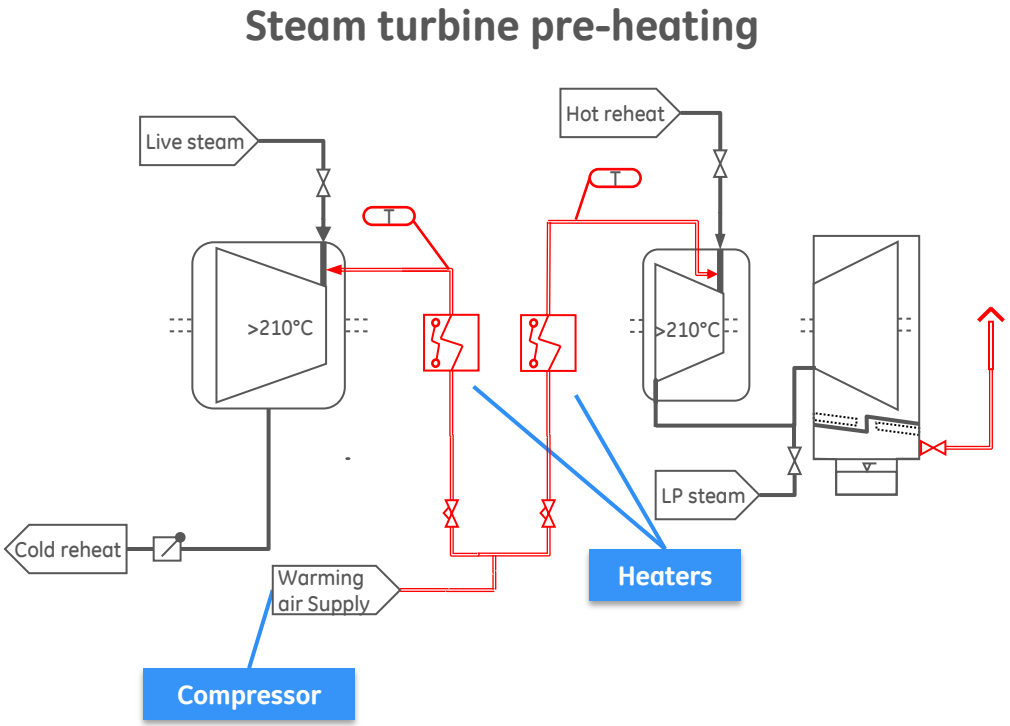
Steam temperature control:

- GT inlet guide vane schedule
- Uprated or additional desuperheater
  - Economizer bypass
- Ambient air injection
  - Reduces life consumption of pressure parts and gas path components of HRSG

Power optimized startup to support the capacity market

Keep steam turbine warm

- Improve the startup in cold condition by actively keeping ST in warm condition
- Reduce lifetime consumption
- Preserve ST during standstill
- Maximum benefit for cold starts

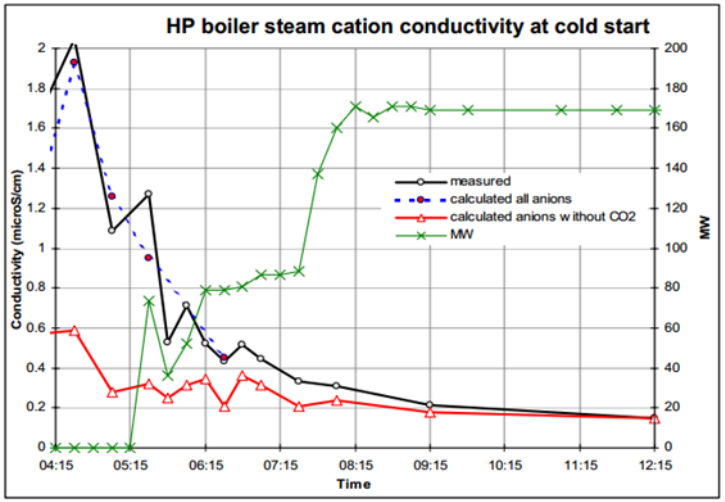


Improved chemical sampling

Degassed conductivity measurement

Sampling arrangement for cycling:

- Remote on/off: switch off during stand still to maintain heat and water level
- Remote sample line flushing
- Automatic pressure and flow regulation for different steam conditions



Phase 3:
Combined cycle loading

Improvement potential during CCPP loading phase (phase 3)

Increase GT loading gradient:

- HRSG life study, trade off between life and economic opportunity

Pre-warming:

- ST

  For increased gradient
- HRSG

  For reduced life consumption

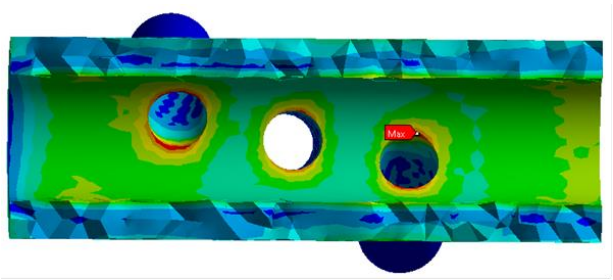
HRSG remaining life assessment

Different levels of detail:

- Level 1: basic life assessment
  - Calculation of creep & fatigue in accordance with boiler design code
  - Corrosion risk assessment
- Level 2: on-site assessment
  - Inspection and condition assessment
- Level 3: finite element analysis
  - More detailed review for critical components

Component	Fatigue Damage	Creep Damage	Total Damage
HPSH1 Outlet manifold	0.477	0.051	0.529
HPSH1 tube-to-header connection	0.022	0.160	0.181
HPSH3 to HPSH2 links (bends)	0.010	0.028	0.038
HPSH3 lower tube-to-header connection	0.132	0.080	0.211
HP Drum - ID/crotch of large penetrations	0.298	0.000	0.298
FWHTR3 tube-to-header connection	0.009	0.000	0.009

Typical output of level 1 assessment



Case studies

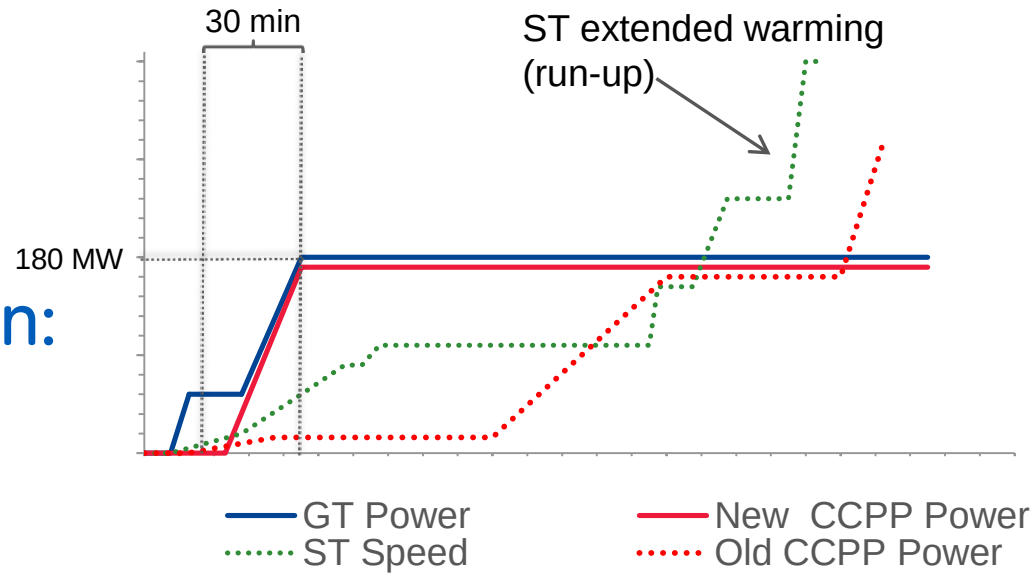
Case study: KA26-1 in Europe

Requirement:

- Dispatch from any condition (cold/warm/hot) to 180 MW within 30 minutes

Elements of GE solution:

- Start and load GT with ST on by-pass
- ST is started later:
  - GT Exhaust temperature optimization
  - New HP/IP desuperheaters setpoints
  - Steam turbine warm-up logic



180 MW in 30 minutes (1x GT only, cold start, ST to follow)

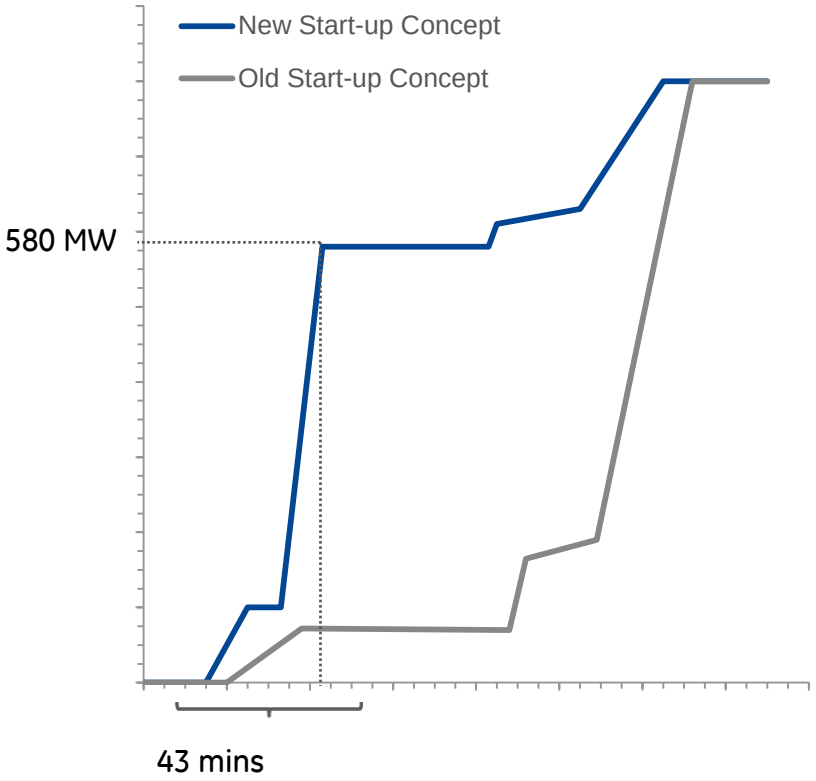
Case study: KA26-2 in Europe

Requirement:

- Short notice dispatch from any condition (cold/warm/hot) to full GT load within 45 minutes (tertiary reserve

Elements of GE solution:

- Purge credit
- Fast condenser evacuation
- New GT and ST start operation concept
- Increased GT and ST loading gradients



580 MW in 43 minutes (2x GT only, cold start, ST to follow)

Case study: Installation of HPRH line oOEM units in Italy

Requirement:

- The market in Italy requires all CCPP to be flexible and reduce the start-up time below 1 hr

Elements of GE solution:

- Modelling and design of new warm-up line
- Noise study
- INAIL certificate (local authorization body)
- Structural verification
- Installation and commissioning

After the installation, the HRH line heating time was reduced from 2.5 hours to 0.5 hours

New warm-up lines

Detail of RH steam vent

Summary

	Phase 1	Phase 2	Phase 3
Keep HRSG warm	X	X	
Keep HRSG and ST warm		X	X
Purge credit	X		
Uncouple Gas and Steam cycle: - VIGV - Desuperheater - Ambient air injection		X	X
Improved sampling		X	
HRSG life assessment and GT and/or ST gradient increase			X
Dispatch and startup optimization on-line tools			X