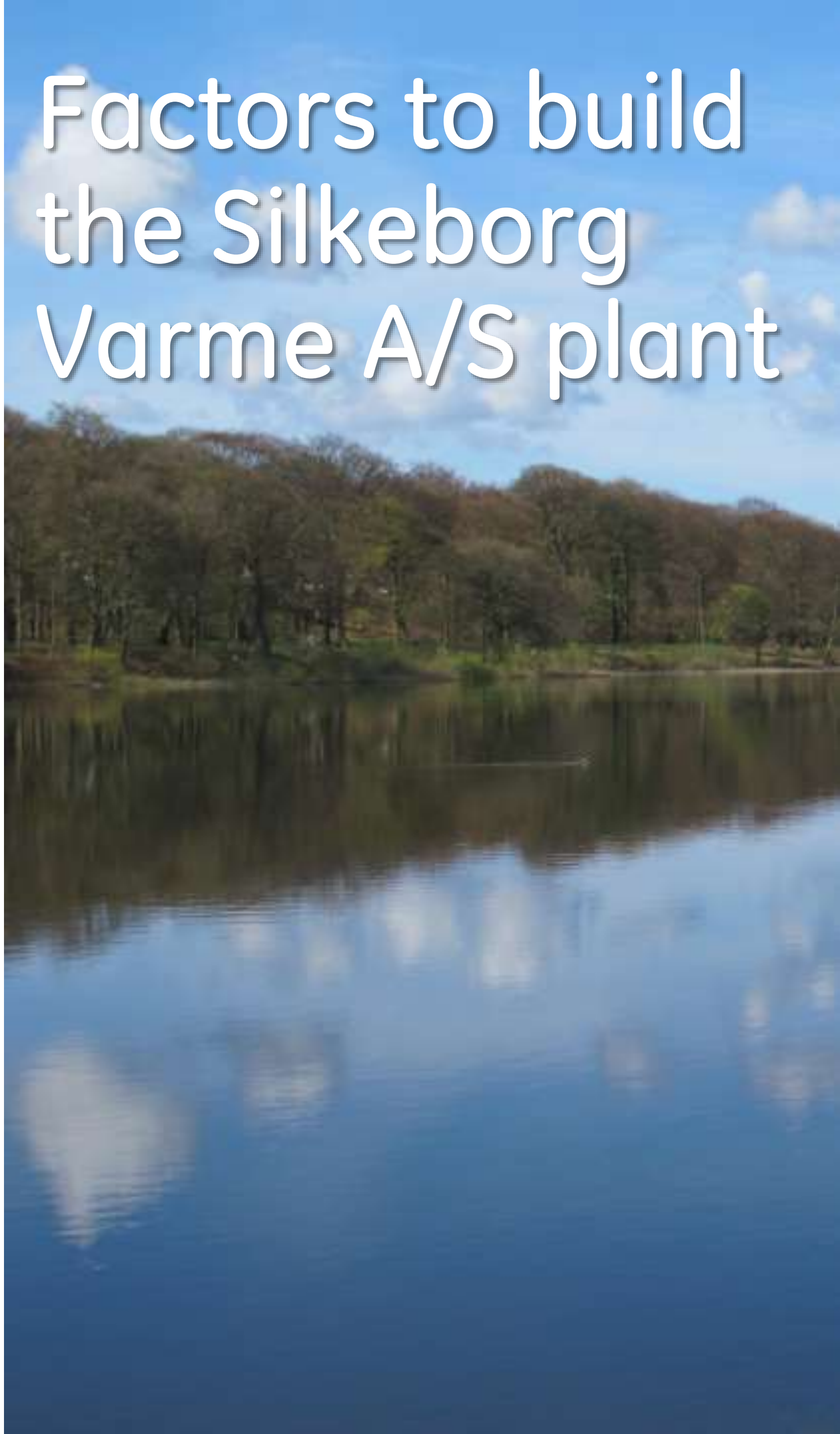
Silkeborg Varme A/S
Evolution of a plant to meet the changing market conditions

Ivan Bach
AeroDerivative Gas Turbines

Factors to build the Silkeborg Varme A/S plant



- Political pressure to reduce CO_2 emissions
- Gas available from North Sea
- "CO_2 10 øre" subsidy encourages new cogen plants
- Transition to natural gas encouraged
- Silkeborg was imposed to build a gas fired Cogen

Erection of Silkeborg CHPP

October 92	Private limited company, Silkeborg Kraftvarmeværk I/S established.
April 94	Cut of the first turf.
October 94	Topping-out ceremony
July 95	First fire Gas Turbine 1 (190-208)
July 95	First fire Gas Turbine 2 (190-209)
August 95	First Power to the grid
November 95	30 days testing period
December 1, 95	Commercial Operation began

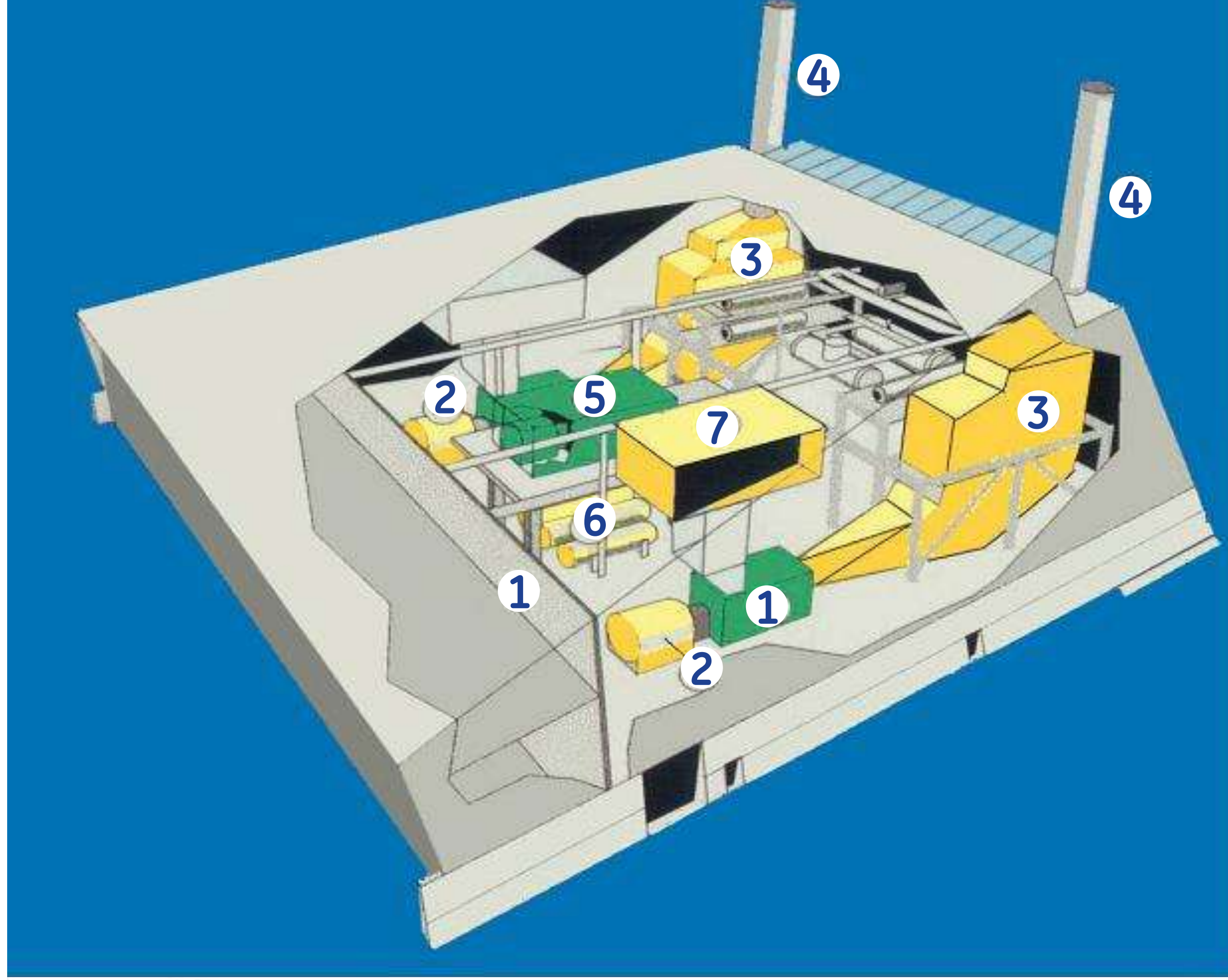
The Silkeborg Varme A/S plant

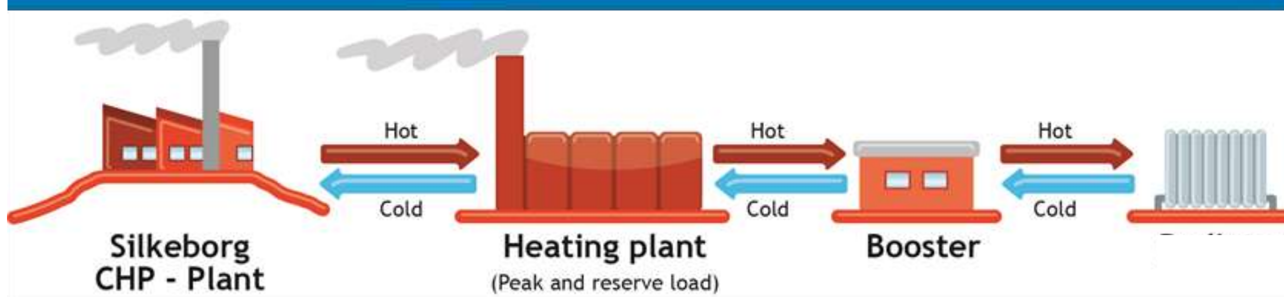
Designed by “arkitektgruppen århus”

Winner of the design competition for the plant

Plant layout

1. LM6000 GT
2. Generator
3. HRSG
4. Exhaust stack
5. ST generator
6. District heating condensers
7. Air inlet






NG Station
Silkeborg Varme A/S
40 dBA!!
LT Coolers
10/60 kV
Station
Heat Storage Tanks

Changed market conditions

December 97	The "CO_2 10 øre" was reduced to 7 øre
Summer 02	Installed additional Districting Heating Economizer's HRSG
October 04	Silkeborg takes full ownership of the plant
December 04	End of the "CO_2 10 øre"
January 05	The Danish electricity is fully deregulated

Drivers to re-think business model

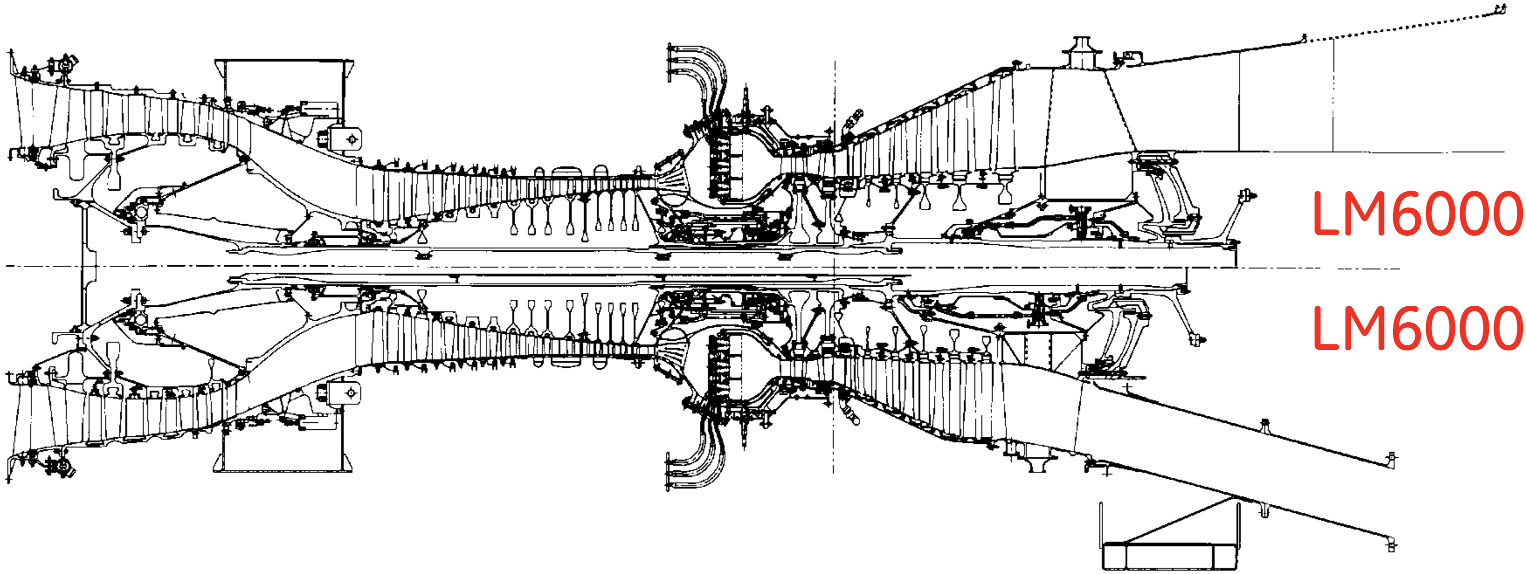
- No other cooling medium other than the “district heating water”.
- Operating hours is limited by district heating consumption / district heating storage capacity (1000 MWH)
- Operating pattern ~4500 operating hours and ~230-250 starts p.a.
- Attractive pricing for fast start capabilities and peak power
- An HRSG by-pass would enable Silkeborg to act in the fast start and peak power market

Drivers to upgrade

- Turbines approaching major overhaul
- LM6000PB LPT technology limited use of HRSG by-pass damper
- Upgraded technology would
  - allow unlimited HRSG by-pass operation
  - improved efficiency
  - electric output

GE imagination at work

LM6000-PB vs. -PD similarity
Allows for easy repowering



Minor dimensional differences were addressed:

- The LM6000PD is 140mm longer
- The turbine rear frame diameter 70mm larger
- The LM6000PD is almost 400kg lighter
- The position of lifting points was also changed

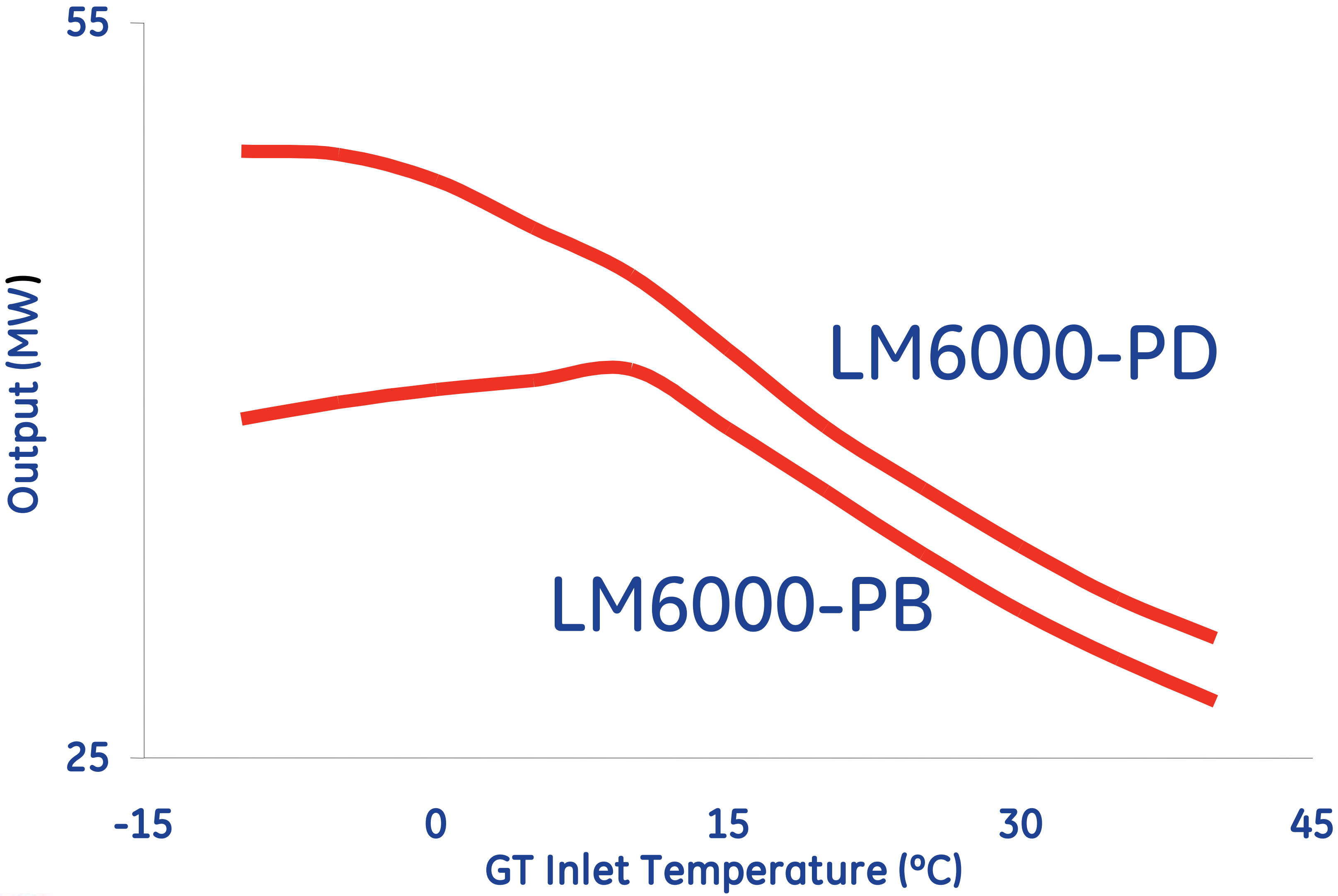
GE imagination at work

Technology selection

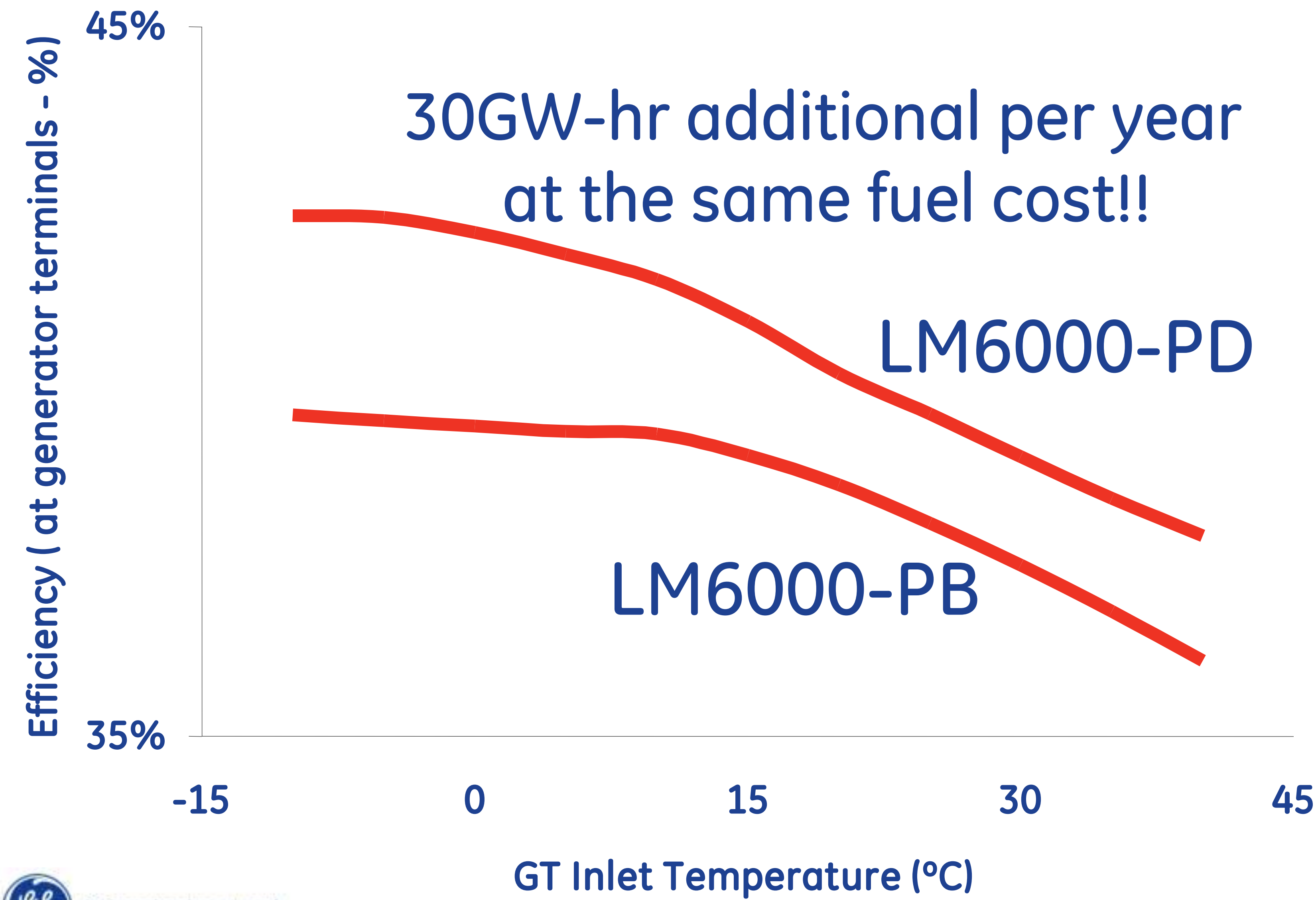
1. Major overhaul currents LM6000PBs
   - limited HRSG by-pass damper operation
2. Upgrade current LM6000PB to LM6000PB Upgrade
   - unlimited HRSG by-pass damper operation
   - increase output
   - improved efficiency
   - would create a hybrid of hardware with different age
3. Exchange LM6000PBs to new LM6000PDs
   - unlimited HRSG by-pass damper operation
   - increase output
   - improved efficiency
   - new hardware – new engine warranty
   - limitation in the gearbox and generator would not allow the full use of the additional power
4. Exchange LM6000PBs to new LM6000PD Sprint®
   - unlimited HRSG by-pass damper operation
   - increase output
   - improved efficiency
   - new hardware – new engine warranty
   - limitations in the gearbox and generator would not allow the full use of the additional power from the Sprint® system

GE imagination at work

Increased output at all temperatures



Significant efficiency gains

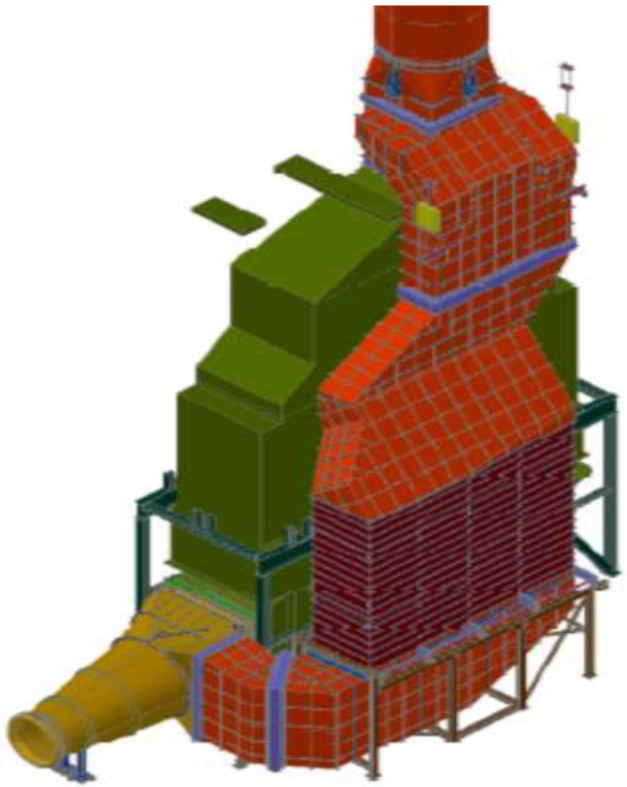


HRSG by-pass damper and exhaust by-pass

Diffuser between gas turbine and HRSG was replaced to accommodate longer and wider LM6000PD and include the HRSG by-pass dampers

Exhaust bypass with silencers was mounted parallel with HRSG

Top part of HRSG and exhaust stack was replaced to accommodate the increased temperature when operating in by-pass



Successful conversion

First upgrade was completed summer of 07; second was completed summer of 08

Electric output increased ~4%

Thermal output reduced by ~4MW thermal

Overall cogeneration efficiency was improved by 1.7% points

LM6000PDs with the new bypass stack system have demonstrated the ability to complete 10-minute starts

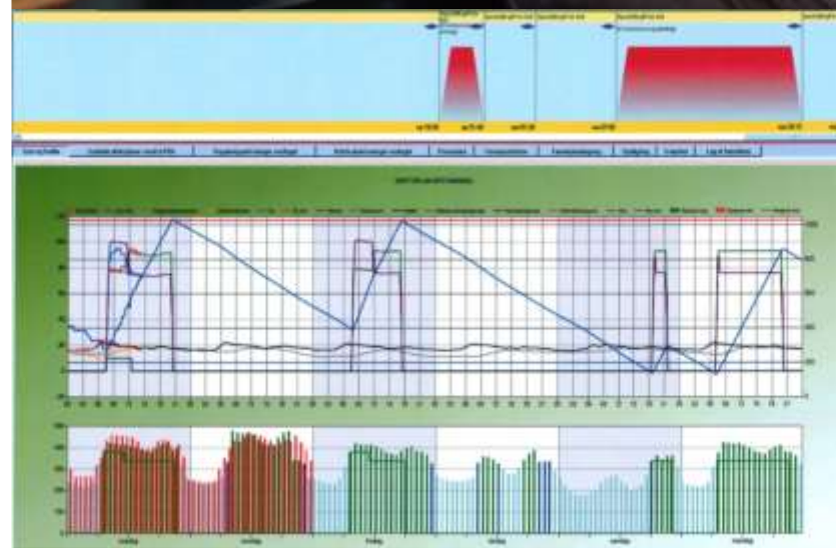
Implemented in less then 6 weeks

Operation and dispatch planning

DCS
The overall control system is based on an ABB 800Xa system

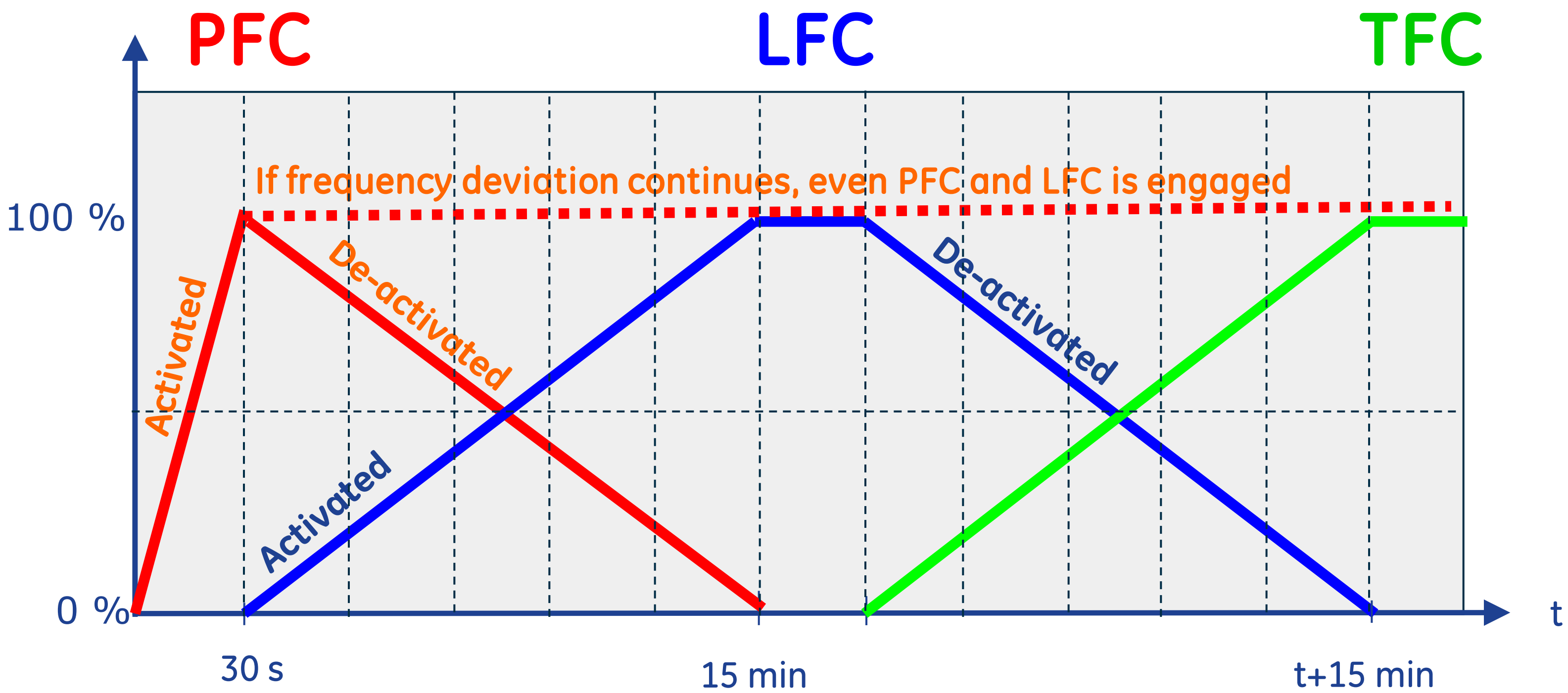
WEATHER FORECASTS
Silkeborg CHP is connected online provider of weather forecasts.
The weather forecast is used in automated process for planning the daily operation

REMOTE MONITORING
Outside normal working remotely monitored and operated the plant from VERDO A/S in the cite of Randers (50 km from site) via a telephone-/internet connection



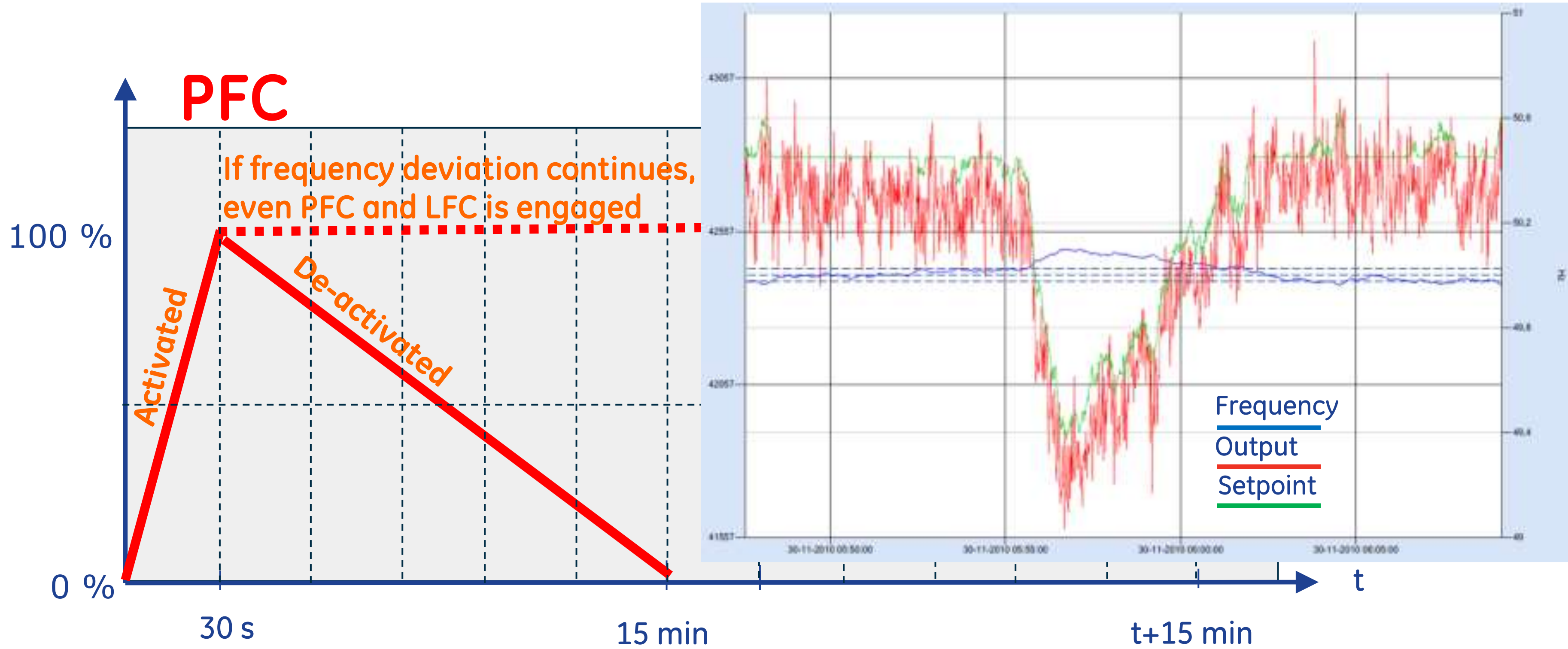
GE imagination at work

Ancillary Services



- Authority - European Network of Transmission System Operators for Electricity (ENTSO-E organizes the TSO's)
- Tolerance for activation +/- 20 mHz (49.98 / 50.02 Hz)
- Full activation +/- 200 mHz (49.8 / 50.8 Hz)
- Staged activation – PFC, LFC and TFC

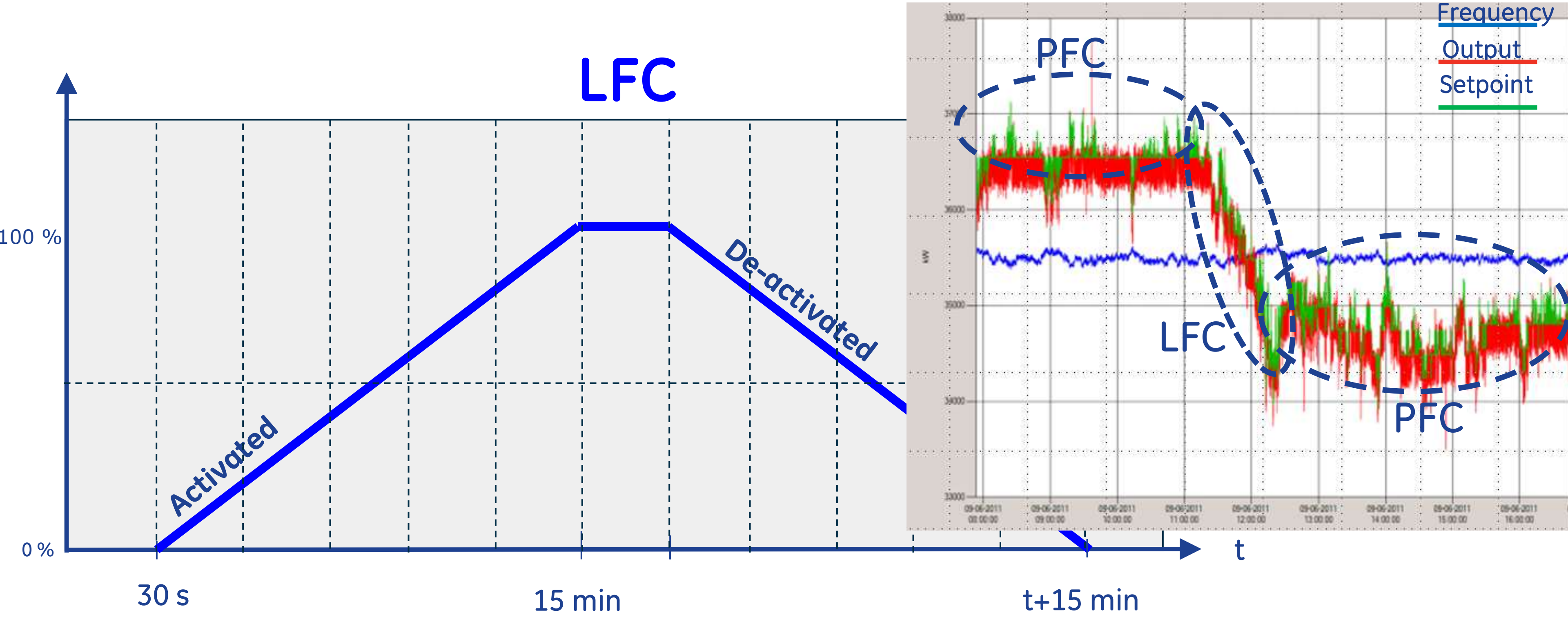
PFC-Primary Frequency Control



- Automatic reserve – based on frequency measured at the site.
- Instant activation
- Linear activation
- Fully activated in 30 sec.
- 1-3 % of grid capacity

GE imagination at work

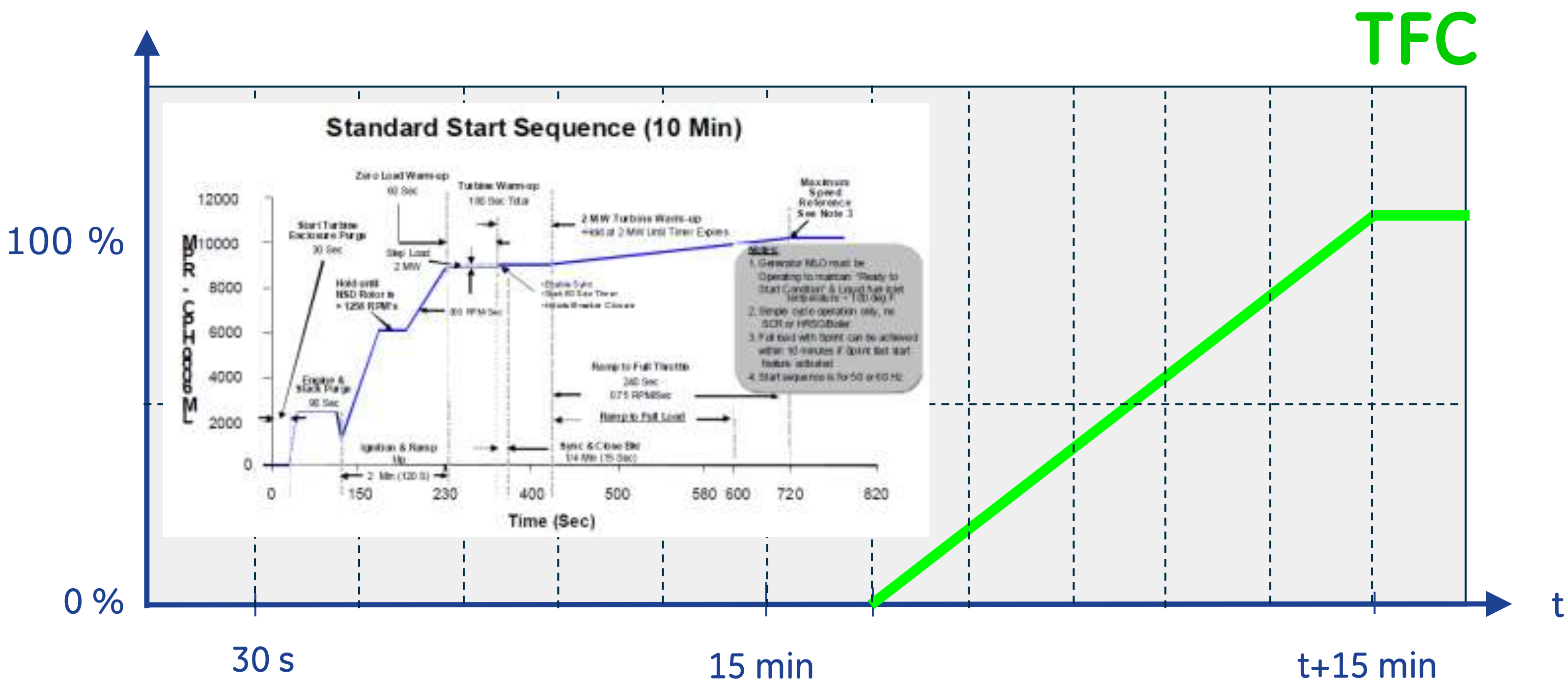
LFC-Load Frequency Control



- Controlled reserves - external set point from TSO's to operators.
- Being activated after 30 sec.
- Fully activated in 15 min
- 10 % of grid capacity

GE imagination at work

TFC-Tertiary Frequency Control



- Manual reserve - input from TSO to operators by phone
- Being activated after 15 min
- Fully activated in 15 min
- 20 % of grid capacity

GE imagination at work

Thank you.

GE imagination at work

imagination at work

Principal Data

	Before	After
Electrical Production, net	98,5 MW	102 MW
District Heating Production, net	86 MW	82 MW
Electrical efficiency	49,1 %	50.50%
Overall efficiency	87.50%	89.20%
Gas Turbines		
Electrical Output	39,0 MW	42.5 MW
Efficiency	39,5 %	40.50%
Flue Gas Temperature	465 °C	460 °C
NOx-emissions	25 ppm	13-15 ppm
HRSG's Boilers		
HT-steam Press./Temp./Flow	63 bar / 452 °C / 11,98 kg/s	55 bar / 450 °C / 11.2 kg/s
LT- steam Press./Temp./Flow	3,6 bar / 235 °C / 4,29 kg/s	4.5 bar / 235 °C / 4.2 kg/s
Flue Gas Temp. after HRSG's Boiler	68°C	68°C
Steam Turbine		
Electrical Production, net	22,5 MW	19.2 MW
Yearly Production:		
Electrical Production	420 GWh	450 GWh
District Heating Production	1100 TJ	1375 TJ
Gas Consumption	80 mill m3	80 mill m^3

GE imagination at work