Control Reserves with Fossil Fuelled Power Plants

GTZ TERNA
expert workshop
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Content

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Grid frequency control

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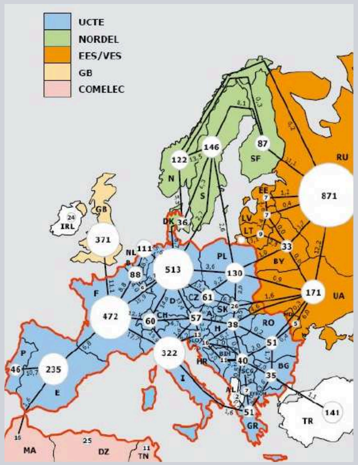
Which tasks have to be fulfilled by the grid?



- Quality of supply: keep voltage and frequency within limits
- Reliability of supply: avoid and control disturbances
- depending on size and structure of grid and generation the tasks are solved differently
- in liberalized markets the minimum requirements to grid participants are defined in Grid Codes

Grid frequency control

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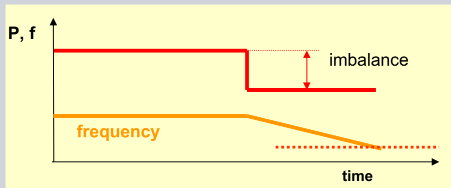
Frequency control

- task: continuous balance between generation and demand



- grid frequency is the integral process value for balance:

$$\frac{\Delta f}{\Delta t} = -\frac{f_n}{2H} \cdot \frac{\Delta P}{P_n}$$

relative demand (or generation) step in the grid

rotational energy of connected machines

- small grids are more affected by disturbances

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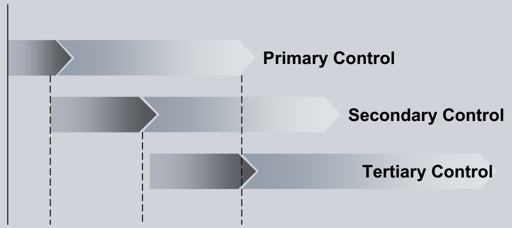
Types of Control Reserve

General definitions:



Primary Control

- effective automatically in participating power plants
- proportionally to the measured frequency deviation (droop)
- release within several sec, to be sustained for up to 15 min

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Types of Control Reserve

Secondary Control in UCTE:

- centralized in control zone
  participating power plants receive setpoint
- restores nominal frequency,
  replaces primary control
- ensures contractual power
  exchange between control zones

$$\Delta P_{di} = -\beta_i \bullet G_i - \frac{1}{T_{ri}} \int G_i \bullet dt$$

$$G = \left(P_{meas} - P_{prog}\right) + K_{ri}\left(f_{meas} - f_0\right)$$

Area Control Error

Tertiary Control

- replaces secondary control
- to be released within e.g. 15 min

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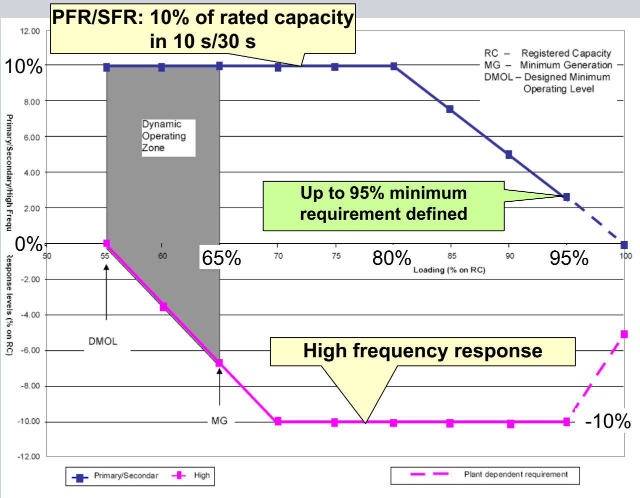
Types of Control Reserve



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Required reserves per power plant, international comparison

PRR/SRR: Primary /Secondary Regulating Reserve, % refers to rated plant capacity

country	Min PRR	within	Min SRR	Dynamics of SRR
Germany	2 %	30 s	30 MW	2%/min
Italy	1,5 %	30 s	6%	8%/min
Greece	3 %	30 s	15 %	15 min
France	2,5 %	30 s	4,5 %	133 s
Netherlands	5 %	30 s	n. a.	n. a.
Norway	2 %*	30 s*	n. a.	n. a.
United Kingdom	10 %	10 s	10 %	30 s
Ireland	5%	5 s	5%	15 s
South Africa	3%	10 s	n. a.	n. a.
Argentina	acc. droop**	30 s	n. a.	n. a.
Singapore	5 %***	8 s	6 %***	30 s

* 2,5% in 5 s at 49.5 Hz (disturbed conditions)
*** above 90% of plant output, below even more
** droop: df/f / dP/P; commonly: 4-5%

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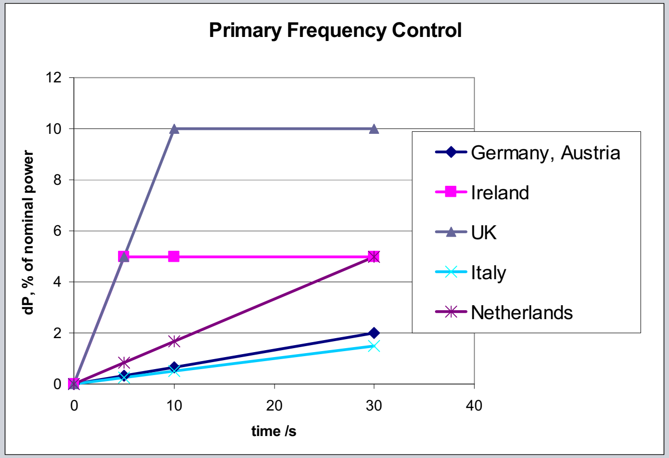
Required reserves per power plant, international comparison



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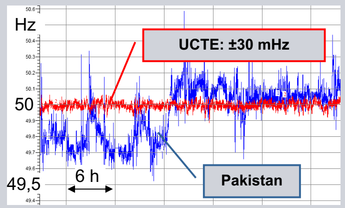
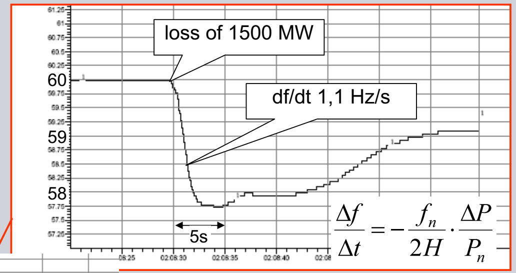
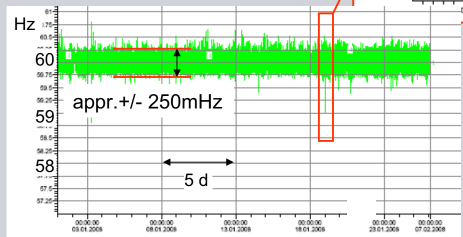
Frequency fluctuations





$$\frac{\Delta f}{\Delta t} = -\frac{f_n}{2H} \cdot \frac{\Delta P}{P_n}$$



Grid	Size
UCTE	380 GW
Pakistan	approx. 12 GW
Philippines	approx. 6,5 GW

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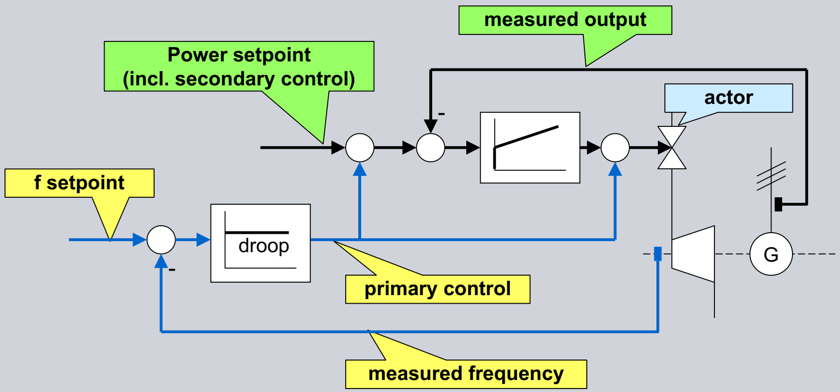
Principle realization in power plant

Power control with primary influence



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Realisation in a coal fired SPP

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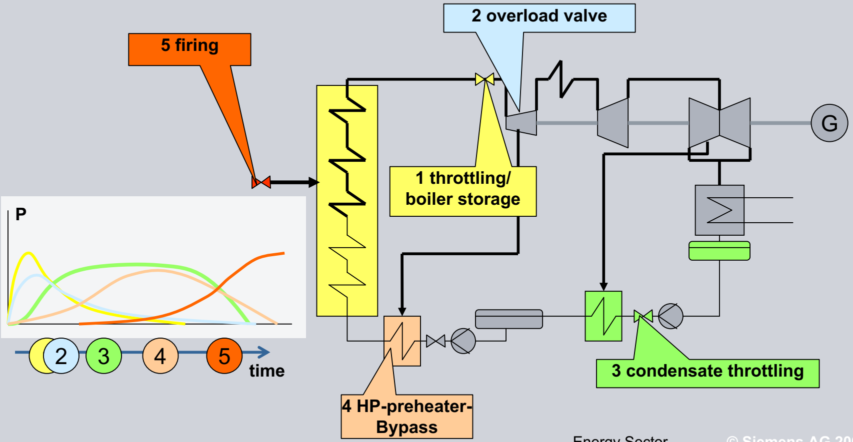
Realization in a coal fired power plant

Possibilites of output increase



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Realization in a Combined Cycle Power Plant

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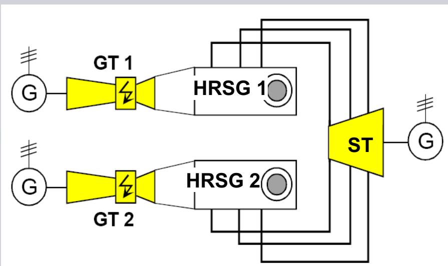
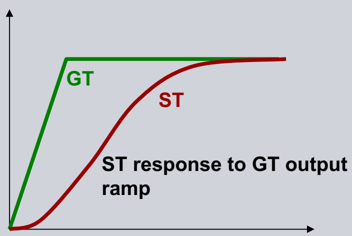
Realization in a CCPP

- efficiency up to 60% by maximum usage of temperature range
- Steam turbine follows gas turbine exhaust with time delay, only GT is able to perform sustained and fast load changes
- reserve capacity of the plant therefore has to be set according power split GT/ST (factor of approx. 1,5)





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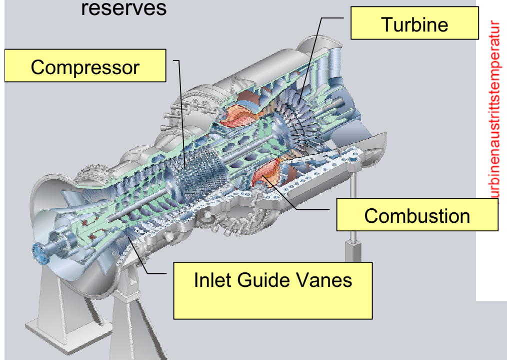
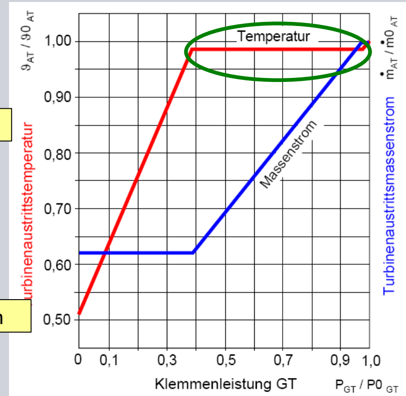
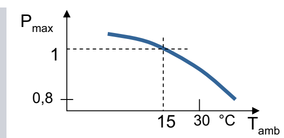
Realization in a CCPP

- constant exhaust gas temperatures allow fast output changes, e.g. for activation of frequency control reserves



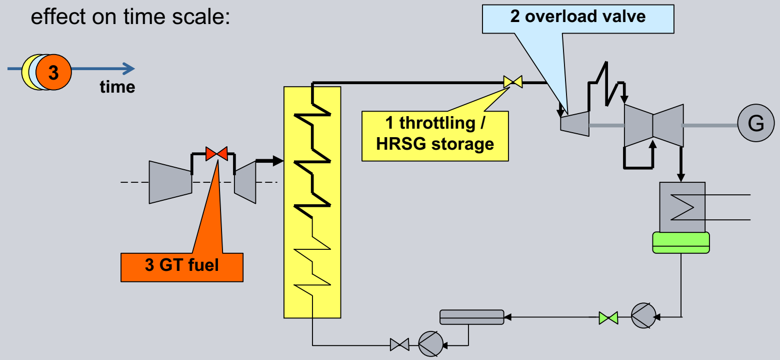


- maximum output of GT depends on ambient temperature

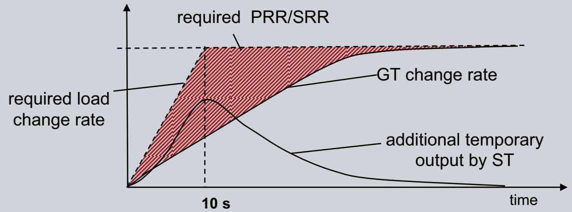


Possibilites of output increase

effect on time scale:

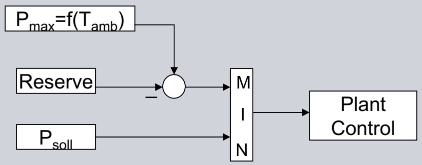


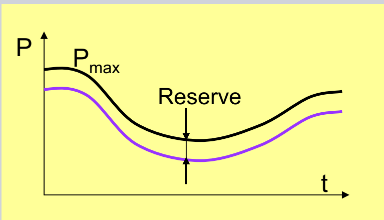
- Limited usage of stored energy, only with reduced efficiency
- normally the dynamic GT behaviour is sufficient
- at high dynamic requirements participation of ST is helpful:



Example:
Primary control in Italy

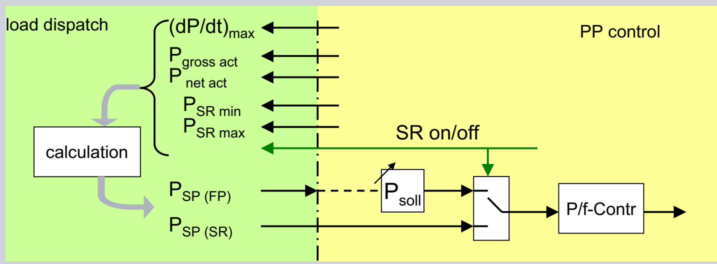
- small minimum reserve (1,5%), but **all** PPs have to participate
- i.e. power reserve has to be available all the time at nominal frequency
- solution: operation with constant control margin to actual maximum power





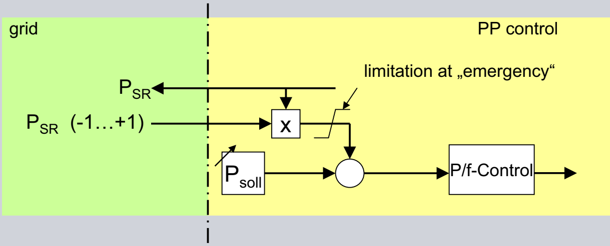
Example:
Secondary control in Germany

- moderate dynamic requirement (min. 2%/min), to be reached after 5 min
- PP receives power setpoint from load dispatcher
- dynamic exchange of current high and low limits and possible transients, load dispatcher calculates and provides setpoint

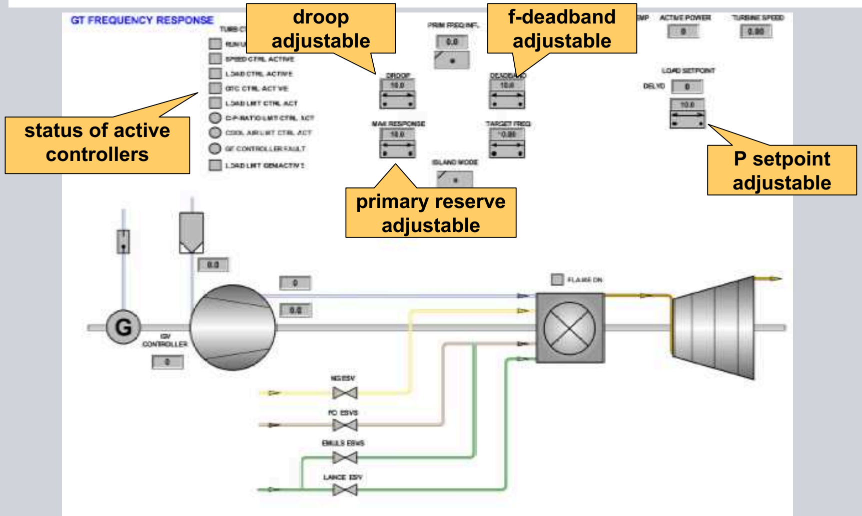


Example:
Secondary control in France

- staggered transient: normal: <4,5% in 800 s
  emergency: <4,5% in 133 s
- PP receives signal -1 … +1 from grid control, PP control calculates MW change
- PP is responsible for providing the agreed control band



Control through MMI of Gas Turbine



Conclusions

- **From a technical point of view the good dynamic properties of gas turbines allow the participation of OC or CCPPs in the control energy market without difficulties**
- **An optimized usage of the energy storages in the water steam cycle provides the required power dynamics also in fossil fired SPPs**
- **When does this participation of a power plant pay-off?**

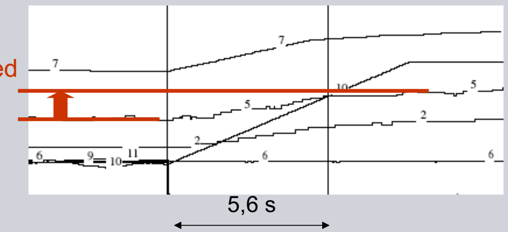
Revenues for the reserve control power (MW) made available Revenues for the reserve energy (MWh) actually supplied	? >	reduced revenues due to part load operation (less continuous MW) higher specific cost per MWh due to reduced efficiency

Retrofit:
Measures in the Automation System

in a Combined Cycle Power Plant

Increase of dynamics of the gas turbines:
- parameters of ramp rate and maximum reserve output
- specifically for adjustment of primary reserve
- possible effects on water/steam cycle have to be considered

Example:
- frequency drop simulated
- gain of 21 MW (5%) within 5,6 s



Retrofit: Measures in the Automation System

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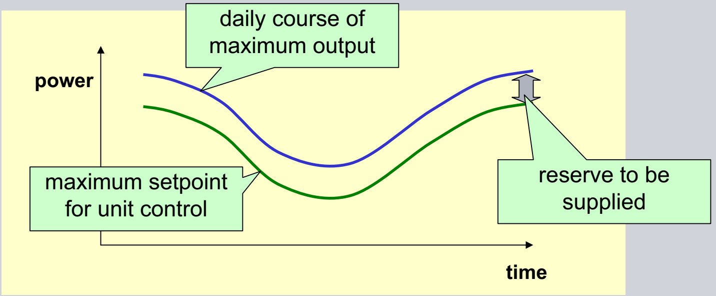
in a Combined Cycle Power Plant :

- „margin controller“: ensures provision of reserve together with maximum gas turbine output



Retrofit: Measures in the Automation System

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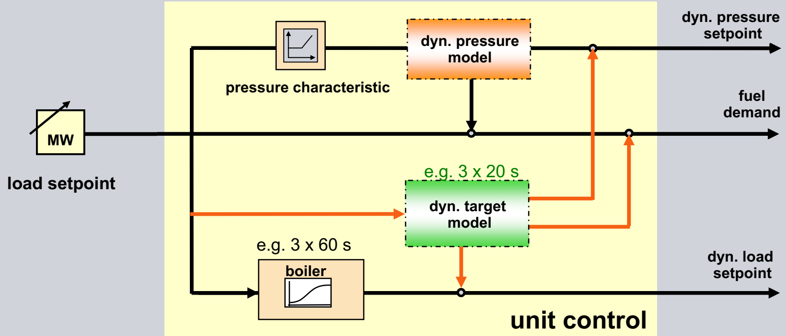
in a steam power plant:

- implementation of model based control improves plant dynamics (Siemens SPPA-P3000, PROFI)



Retrofit: Measures in the Automation System

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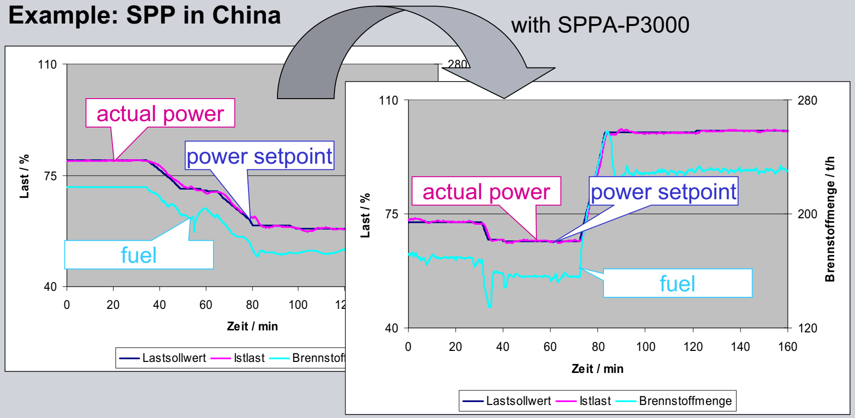
Example: SPP in China

with SPPA-P3000



- increase of load change rates and control accuracy allows participation in the secondary control market

Retrofit: Measures at components

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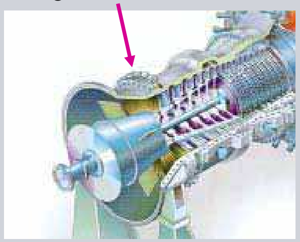
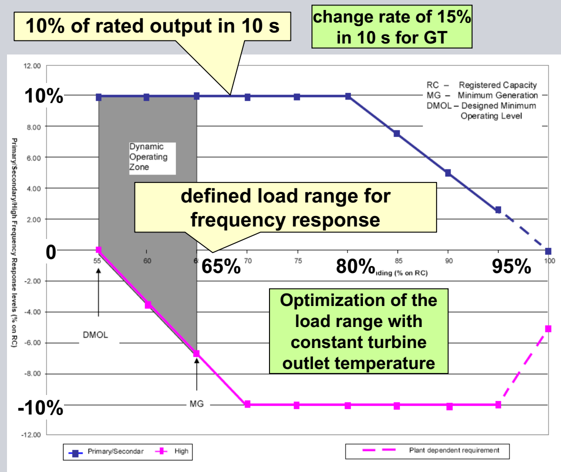
in a CCPP e.g.

- implementation of fast inlet guide vanes in gas turbines



- extension of IGV control range



Retrofit:
Measures at components

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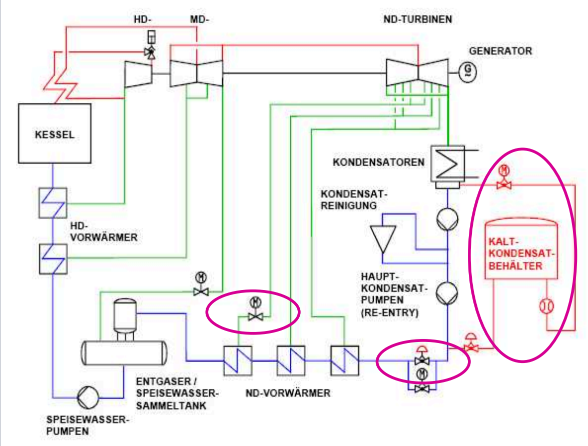
in a SPP e.g.

- additional condensate reservoir
- flaps in steam line to condensate preheaters
- faster valve drives



Procedure of retrofit

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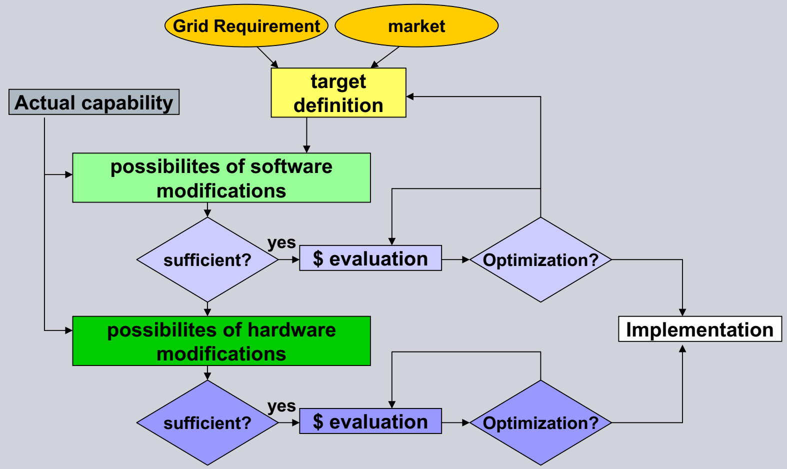

Combination with wind power :
GT-/ CC stand-by power plant

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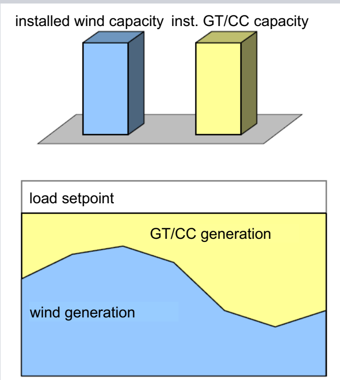

possible task: scheduled output to be met independently of available wind generation

requires broad capacity range of power plant, mainly part load operation, i.e. high invest with bad usage of installed capacity

principall possible for island grids, where gap between actual wind generation and actual demand has to be closed by a power plant

Combination with wind power :
GT balanced the forecast error of a wind farm

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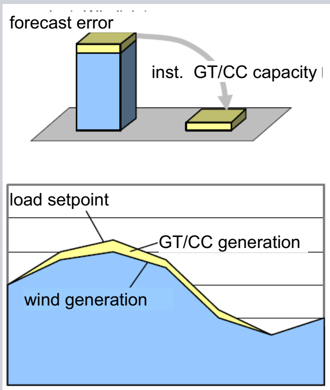

possible task: scheduled output shall meet wind forecast

	2003	2007	2010	2015
Day ahead-WEA-Prognose (% der inst. Leistung)				
Mittelwert	-0,28	-0,29	-0,32	-0,32
σ	7,29	6,77	6,05	5,91
Min	-27,50	-27,50	-24,00	-23,50
Max	41,50	39,00	30,50	29,50
4 h-WEA-Prognose (% der inst. Leistung)				
Mittelwert	1,26	1,16	0,97	0,97
σ	4,92	4,48	3,90	3,8
Min	-17,00	-16,75	-14,50	-14,00
Max	33,00	28,50	24,50	24,25

Source: DENA 2005

GT capacity of approx. 10% of windfarm capacity covers the forecast error:
e.g. 10 MW at 100 MW wind farm capacity

short start up times (few minutes) allow flexible operation

Combination with wind power: base load CCPP with control reserve for forecast error

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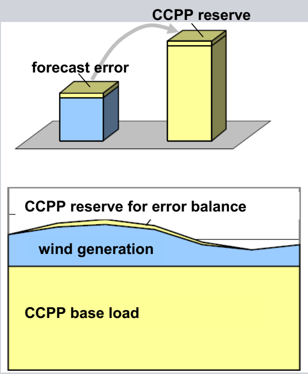

task: load setpoint based on wind forecast, CC close to base load, reserve power covers forecast error

combination of high base load efficiency of a CCPP and its control reserve capabilities with a wind farm

e.g. 400 MW CCPP+ 100 MW wind,
10 MW forecast error
= 2,5 % of CCPP rated output

The Siemens Gas Turbine Product Line Full Product Range for 50 Hz and 60 Hz Grids

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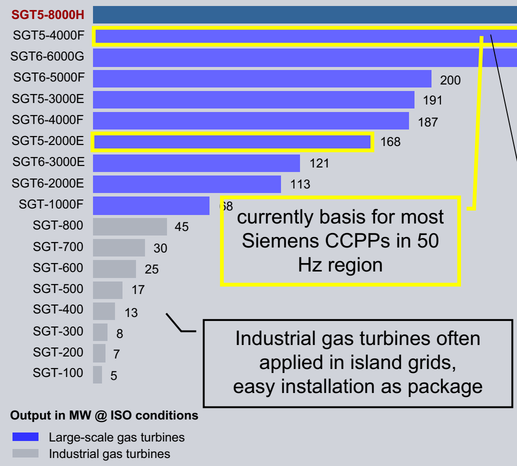

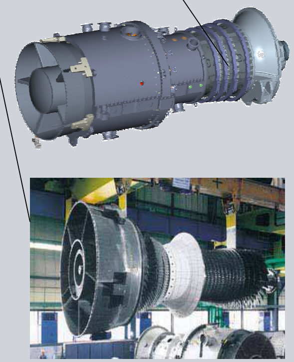

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Thank you very much for your attention!

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