10. BUSINESS STRATEGIES IN ANCILLARY SERVICE MARKETS

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Ancillary service markets US FERC order 888 (1996) determined six ancillary services

- Scheduling, system control and dispaching services
- Reactive supply and voltage control sevice
- Regulation and frequence response service
- Energy imbalance service
- Operating reserve-spinning reserve service
- Operating reserve – supplementary reserve service

Ancillary service (A/S) markets Purpose

- The given six ancillary services (A/S) shall be open to competition
- System operator shall buy all the A/S services needed from the A/S market
- The load service entities (LSE) can generate their own ancillary services and/or sell or buy them from the A/S markets

Ancillary service (A/S) markets
Main A/S markets

- USA separate markets for
  1) Regulation reserve market
  2) Spinning reserve (5 -10 min) market
  3) Non-spinning reserve (10 min) market
- Europe
  1)Secondary frequency control market includes regulation, 10 minute spinning and 10 minute non-spinning reserve markets

Regulation reserve market

Regulation reserve market Purpose

- Manage energy balance in the power system within 5 to 15 minutes
- Restore frequency response reserves (primary frequency control) to be ready for another disturbance
- With open market the prices of regulation reserves will be reasonable (competitive prices)

Regulation reserve market
Costs of regulation

Power plants offer regulation at opportunity costs

$$\mathbf{Oc = Pe - Vc}$$

Where

Oc = opportunity costs of electricity (=loss of profit , if the output will be reduced)

Pe = market price of electricity

Vc = variable costs of power generation

Regulation reserve market
Net revenues from regulation

Power plant can make net revenues in the regulation market if

$$Pr > Oc$$

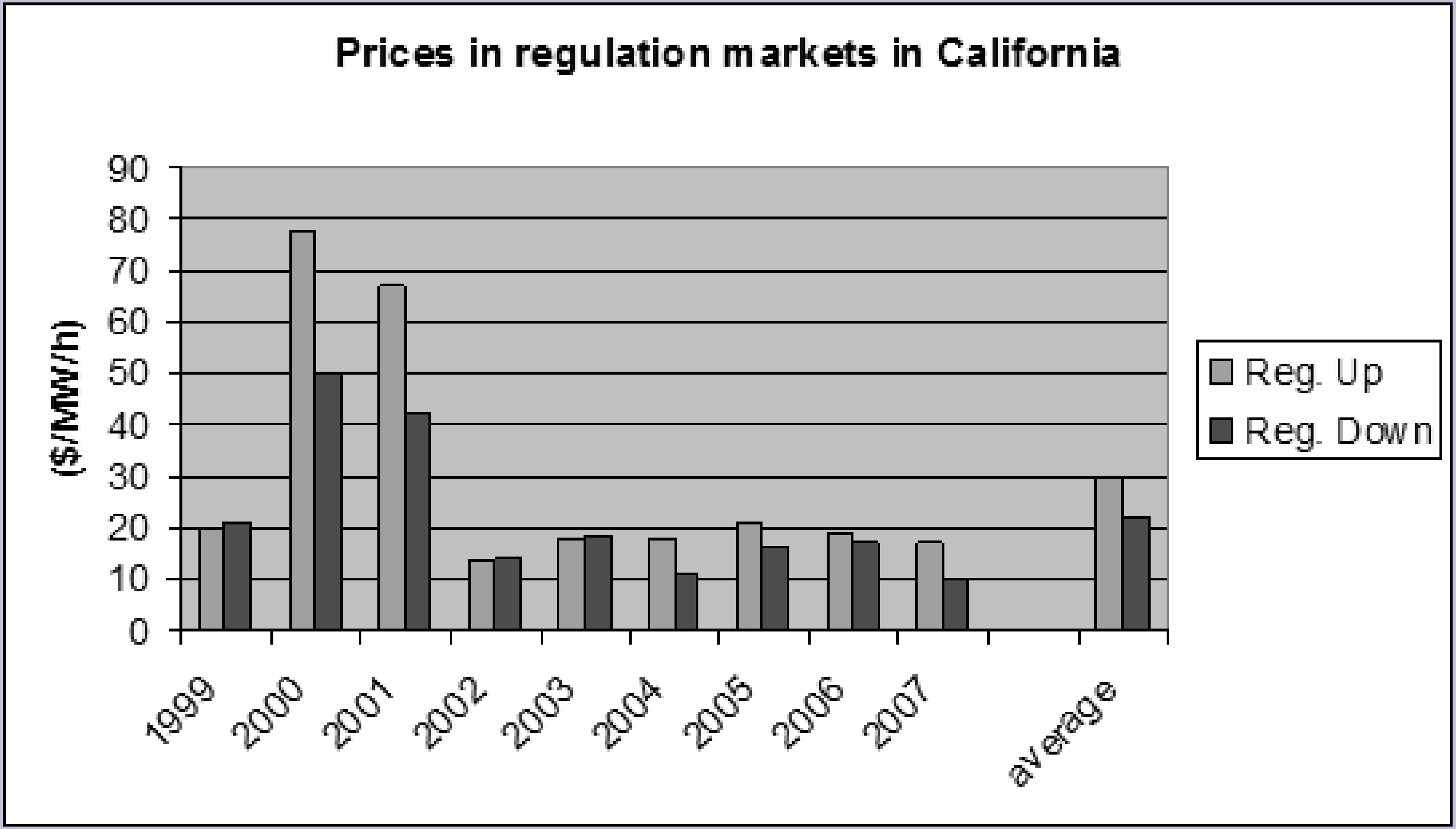
Where

Pr = regulation price (€/MW/h)

Oc = opportunity costs of electricity (€/MW/h)

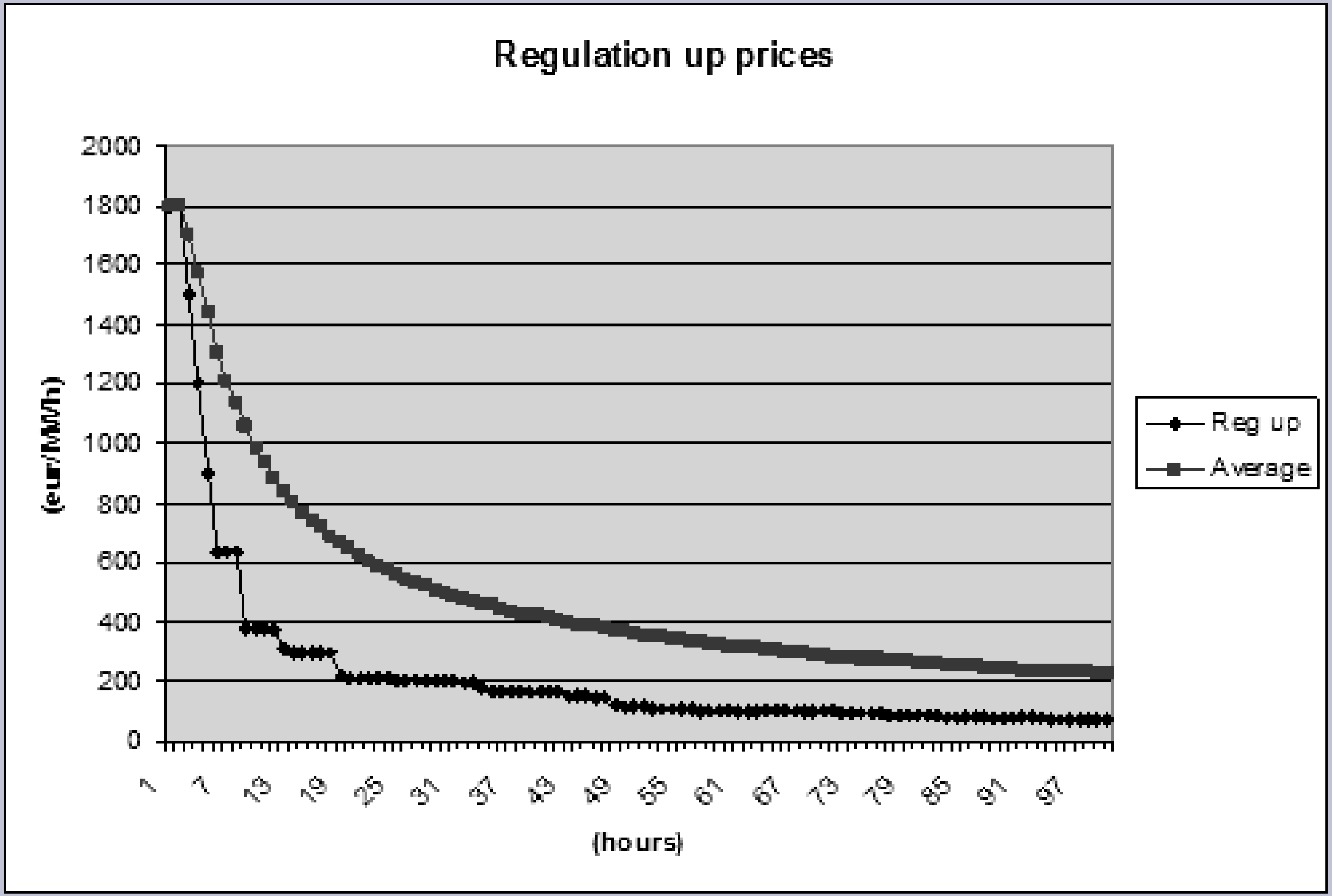
Regulation reserve market

Market prices of regulation reserves in California



Regulation reserve market

Market prices of regulation reserves in Finland, January, 2006

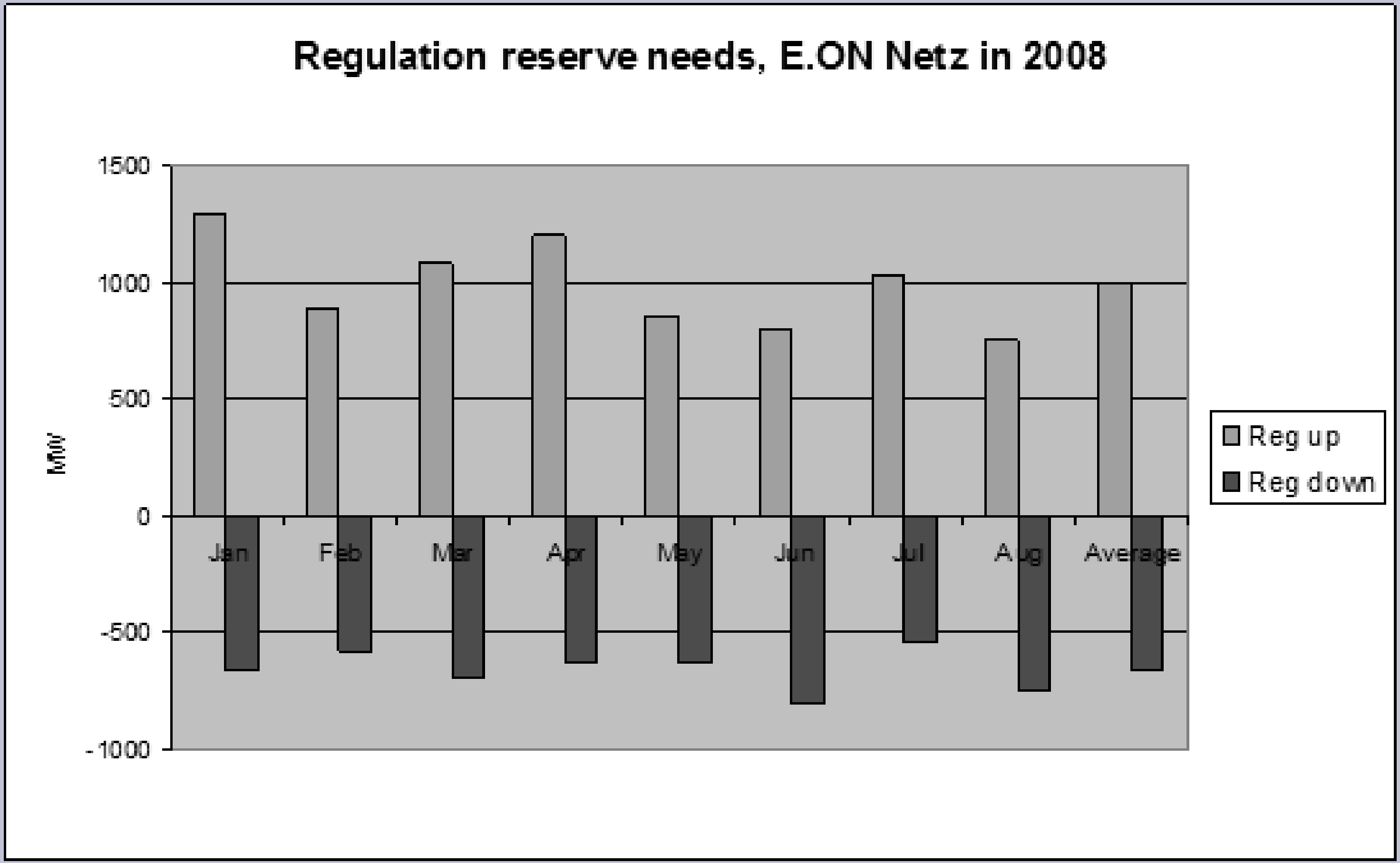


Regulation reserve market volume in Western Denmark

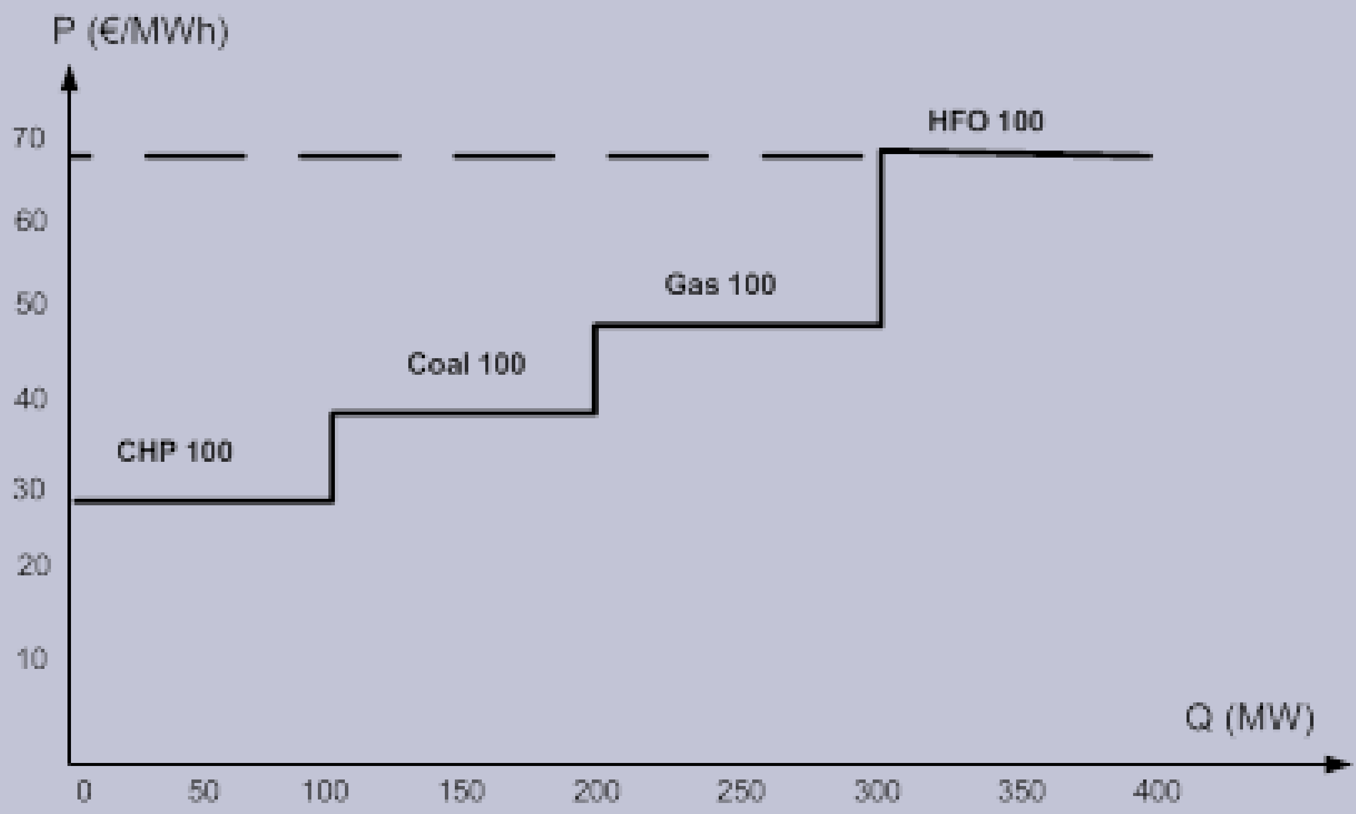
		2005	2012	addition
Total power capacity	*MW*	*7600*	*8300*	*700*
Wind power capacity	*MW*	*2535*	*3260*	*725*
Regulation up reserves	*MW*	*1700*	*2100*	*400*
Regulation down reserves	*MW*	*1000*	*1400*	*400*

Wind power is increasing the need for reguating reserves:
Reg. up reserves = 64 % of wind capacity
Reg. down reserves = 43 % of wind capacity

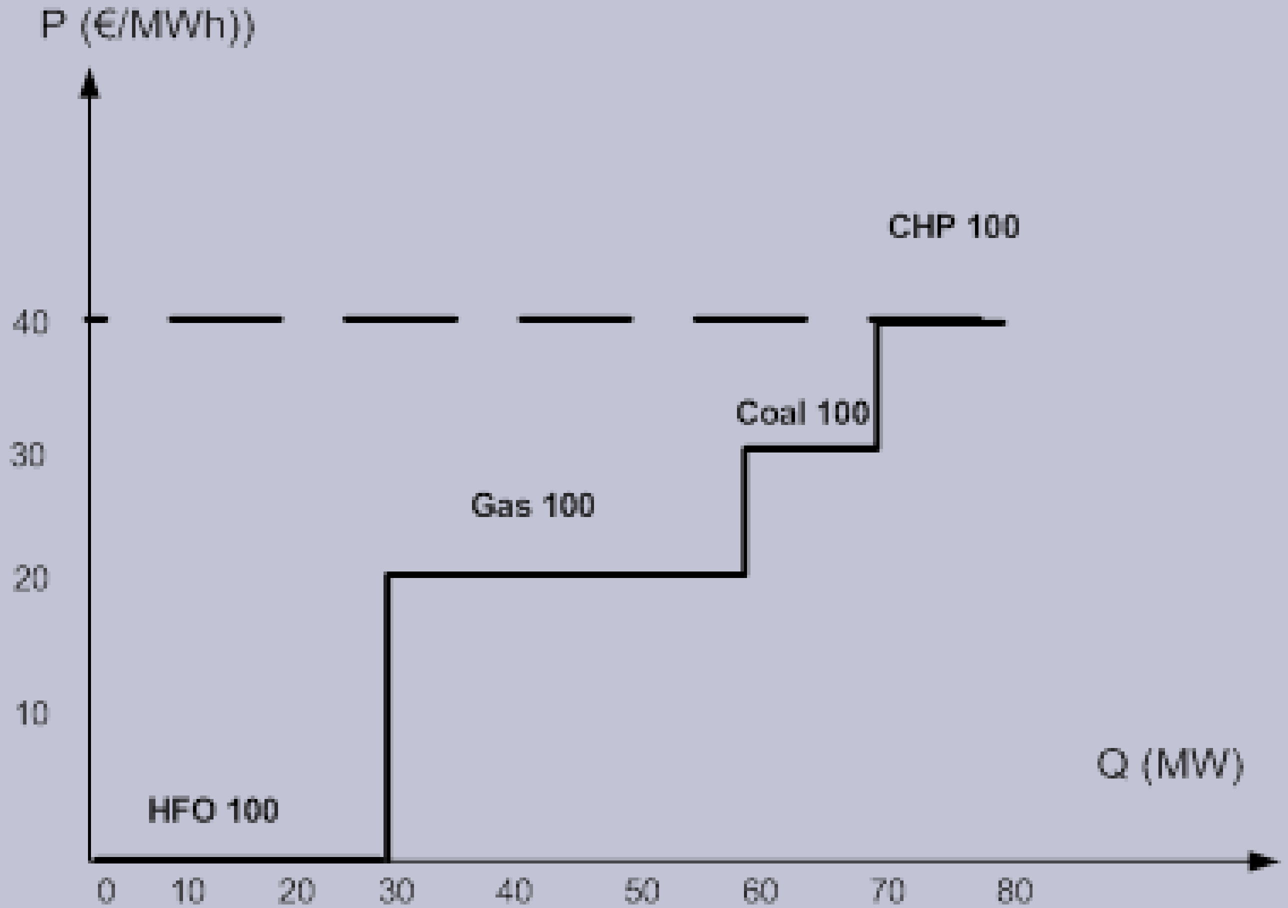
Regulation reserve market volume in E.ON Netz, Germany



Electricity supply curves of 100 MW power plants



Regulation power supply of 100 MW power plants



Regulation reserve market

Net revenues from regulation

- If the price of electricity Pe = 60 €/MWh and variable costs Vc = 50 €/MWh then opportunity costs Oc = 10 €/MWh
- If a power plant reduces its output from 100 MW to 70 MW, it loses its opportunity costs (30 MW x 10 €/MWh = 300 €/h)
- But if price of regulating power Pr = 20 €/MW/h, the regulation revenues are 30 MW x 20 €/MW/h = 600 €
- The net revenues from regulation are then 600 €/h – 300 €/h = 300 €/h

Regulation reserve market

Regulation increases net revenues

Energy market only

1) Net revenues from energy market

   = 100 MW x (60 – 50) €/MWh = 1000 €/h

Energy + regulation

1) Net revenues from energy market=

   70 MW x (60-50) €/MWh = 700 €/h
2) Net revenues from regulation = 30 MW x 20 €/MW/h = 600 €/h
3) Total = 700 + 600 = 1300 €/h or + 30 %

Regulation reserve market

Summary

- Flexible power plant can increase their net revenues by operating in part load and selling regulation up/down (+/-) power
- Increase of net revenues is the difference between revenues from regulation and loss from energy profits

Spinning reserve market

Spinning reserve market Purpose

- Restore regulation reserves (with non-spinning reserves) after a trip of the largest unit within 5 or 10 minutes
- Spinning or synchronized reserves act immeditely by the rotating mass (inertia) of rotor and flywheel, when frequency deviates from nominal value

Spinning reserve market

Generation of spinning reserves

- Spinning reserve plant offer to increase its output from P_{min} to P_n
- Typical internal combustion engine or gas turbine plant can operate constantly at 40 % load (P_{min}) and increase its output to 100 % (P_n) in 5 or 10 minutes

Spinning reserve market

Costs of spinning reserves

Cspin = Pn x (Pe – Vcn) – Pp x (Pe – Vcp)=

= Pn x Pe – Pn x Vcn – Pp x Pe + Pp x Vcp

Cspin/(Pn-Pp) = Pe – Vcn x (1 – Pp/Pn x Vcp/Vcn)/(1-Pp/Pn)

Where

- Cspin = cost of spinning reserve
- Pn = power output at full output
- Pe = price of electricity
- Vcn = variable costs at Pn
- Pp = power output at part load
- Vcp = variable costs at part load

Spinning reserve market
Costs of spinning reserves

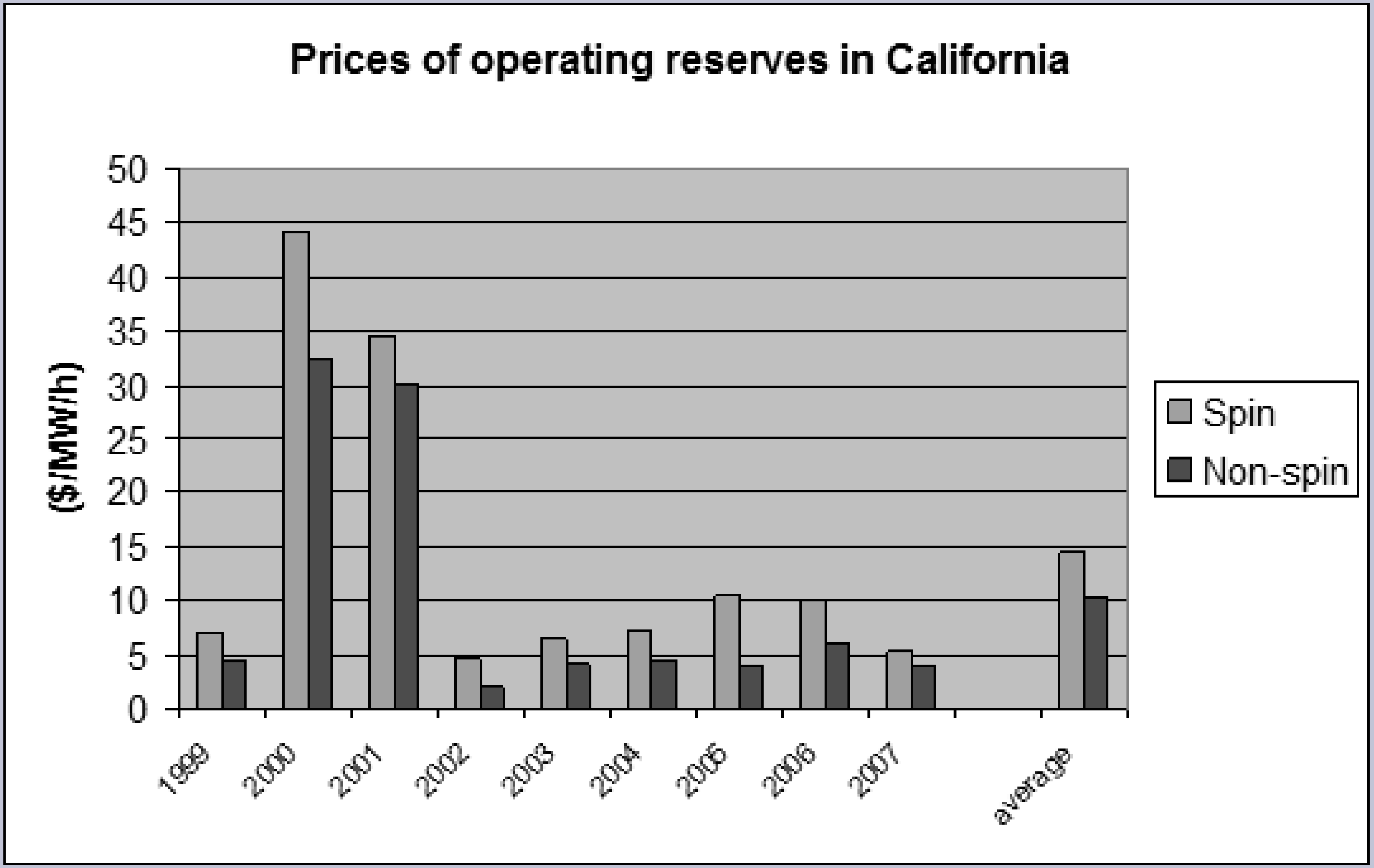
Part load efficiency is important

If part load efficiency is low, then variable costs at part load (Vcp) are higher than at nominal load (Vcn) and cost of producing spinning reserve (Cspin/(Pn-Pp)) will increase*

* see formula in slide 15

Spinning reserve market

Prices of spinning reserves



Spinning reserve market
Net revenues

- If price of spinning reserve is Pspin (eg. 15 eur/MWh)

- Then a power plant increases its net revenues, if the difference of price of electricity and variable costs is less than Pspin (15 eur/MWh)

Spinning reserve market

Summary

- Flexible power plants can increase their profit by operating in the part load and selling spinning reserves
- Increase in net profits is the best if the part load efficiency of the power plant remains high

Non-spinning reserve market

Non-spinning reserve market
Purpose

- Restore regulation reserves (with spinning reserves) after a trip of the largest unit within 5 or 10 minutes
- Non-spinning (unsynchronized) reserves act only after synchroni-sation*

* Synchronisation takes 1 – 3 minutes for diesel and gas engines and 3 – 7 minutes for aero-derivative gas turbines

Non-spinning reserve market

Generation

- Power plant will be in hot stanby mode and is not synchronised
- Non-spinning reserves act only after synchronisation*

* Synchronisation takes 1 – 3 minutes for diesel and gas engines and 3 – 7 minutes for aero-derivative gas turbines

Non-spinning reserve market
Net revenues

$$Nr = (Pnspin \times Pn - Csb) \times tsb$$

Where

- Nr = net revenues
- Pnspin = price of non-spinning power (eur/MW/h)
- Pn = Power output to be sold on nonspin (MW)
- Csb = costs to keep the plant at hot standby conditions (eur/h)
- tsb = annual time at hot standby conditions (h)

Non-spinning reserve market

Net revenues

If the price of non-spinning power will be 5 – 10 eur/kW/h in average

Then a 160 MW plant makes 800 – 1600 eur extra revenues in one hour

The plant could then generate 5 – 10 million euros annually!

Non-spinning reserve market
Summary

- If power plant can start up to full load in ten minutes, it can increase its revenues and sell non-spinning reserves
- The increase in net revenues will be the difference between the non-spinning revenues and the costs of keeping the plant in hot standby conditions

Optimization of power plant operation in A/S markets

Optimization of the operation Power plant owner

- Owner tries to maximize his net revenues by generating energy, regulating, spinning and non-spinning reserves in an optimal mix
- He uses algorithms, which selects the best operation mode for each of his power plants

Optimization of the operation

Algorithm to maximize of net revenues

1) Calculate net revenues if the plant generates only energy at 100 % load
2) Calculate net revenues, if the plant generates energy at 70 % load and offers regulation (+/- 30%)
3) Calculate net revenues, if the plant operates at 40 % load and offers spinning (+60%)
4) Calculate net revenues, if the plant is in hot standby and offers non-spinning reserves (+100 %)
5) Select the one of the four operating modes, which gives the highest net revenues
6) Go to point 1) until all hours have been evaluated

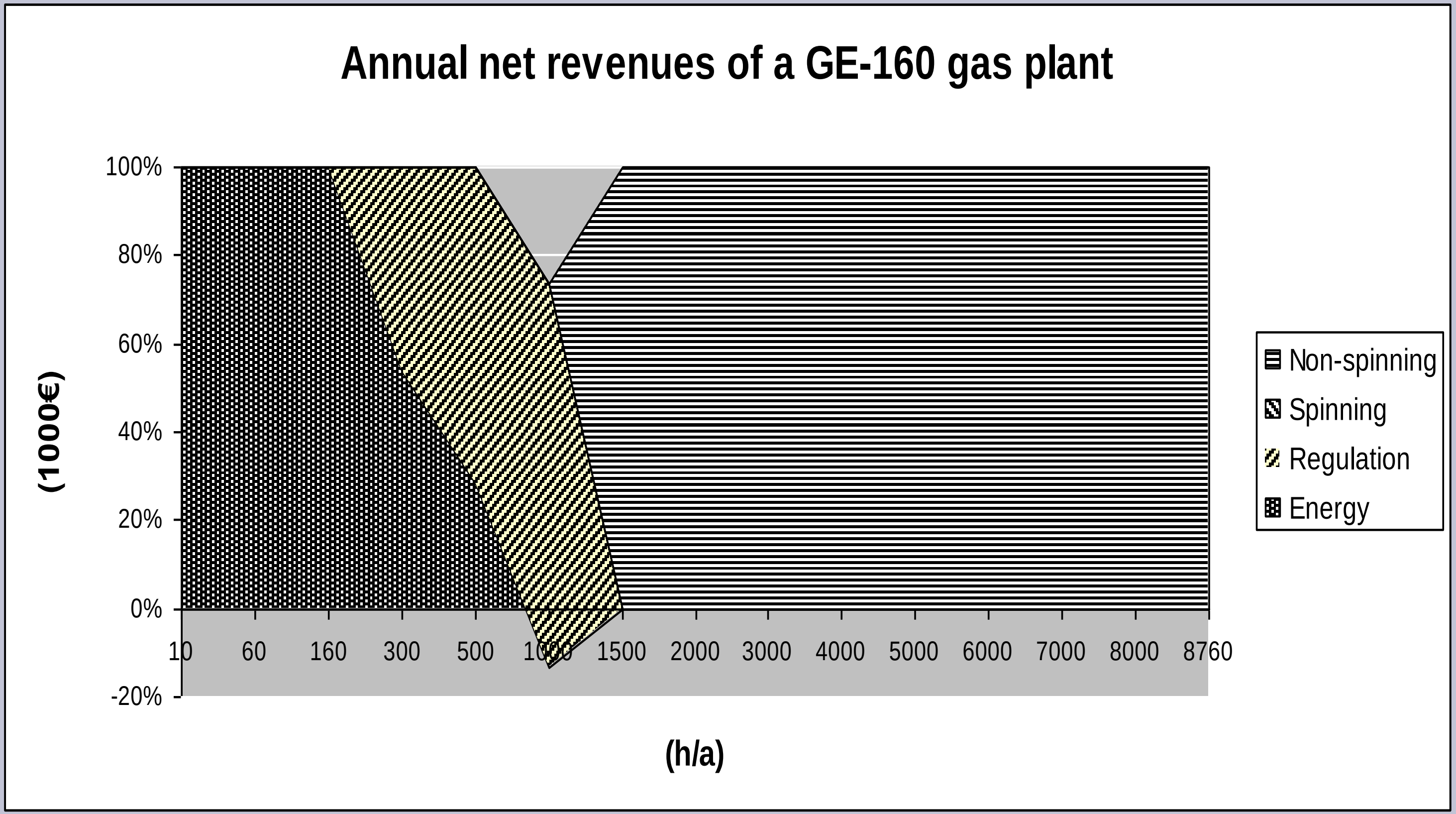
Optimization of the operation
Transmission system operator (TSO)

- TSO should do the optimization one day ahead for all power plants in the system at the same time

- TSO should then determine, how energy, regulation, spinning and non-spinning reserves shall be generated during the next day

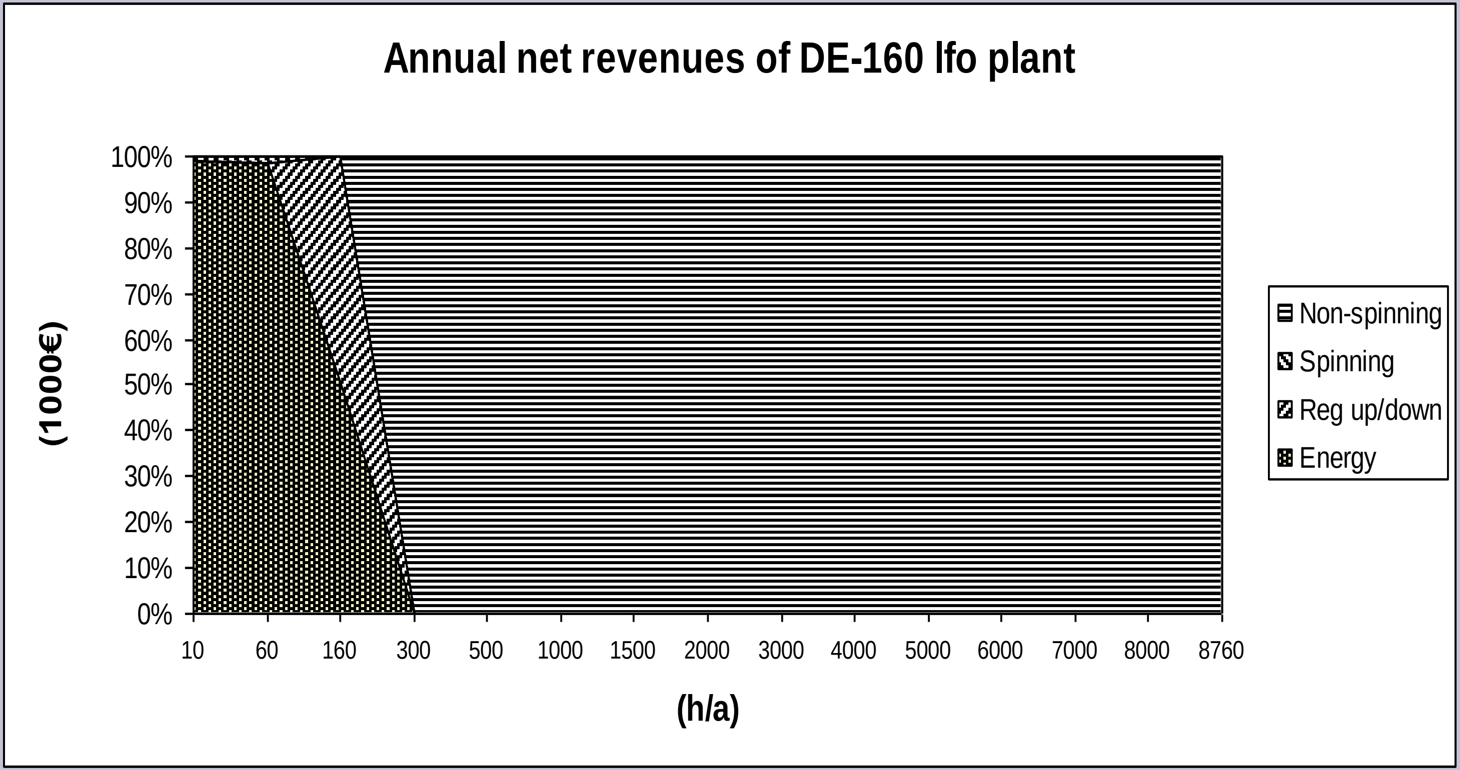
Optimization of the operation

Optimum operation of gas engine plant



Maximum net revenues are found in the base case, if the plant produces 160 hours energy only, 1340 hours energy and regulation and 7000 hours non-spinning power

Optimization of the operation
Optimum operation of diesel engine plant



Maximum net revenues are found in the base case, if the plant produces 60 hours energy only, 140 hours energy and regulation and 8300 hours non-spinning power

Summary and conclusions

- The new energy markets include also ancillary services (A/S markets)
- The optimization of operation of all power plants should be made for energy and A/S markets at the same time
- The flexible peaking plant makes typically 80 % of all net revenues in A/S markets and only 20 % in electricity markets

For details see reference text book
”Planning of Optimal Power Systems”

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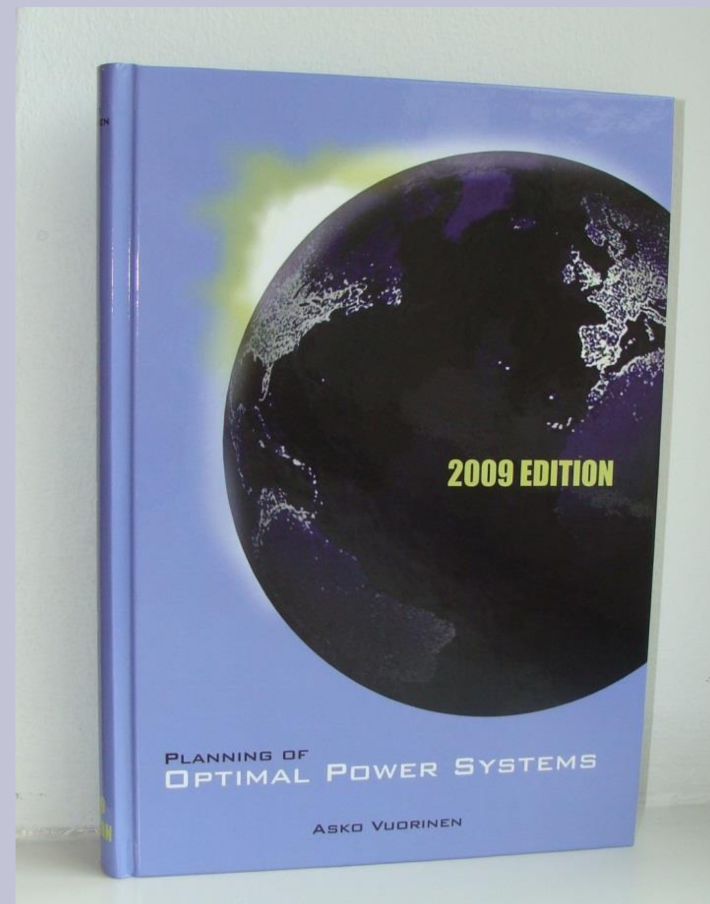

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