Grosskraftwerk Mannheim AG

Operating a coal fired power plant in a flexible market environment

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Seminar on Adaption of Thermal Power Plants to Fluctuating Renewable Energies
The German Experiences (VGB POWERTECH / IGEF / EEC / CEA)

16 December 2016, New Delhi
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1. Introduction / GKM Power Plant
2. Actual situation in Germany („Energiewende“)
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GKM history: the beginnings

1921

GKM is founded on 8th of November

Start of construction work at a good location: close to town of Mannheim and directly sited at river Rhine; start of electricity generation in 1923

Mastermind: Dr. Karl Friedrich Marguerre, Executive Direktor
GKM founded 1921…new unit 9 in erection (2013)…
GKM plant today
CHP process (combined heat and power) in GKM

CHP process diagram:

- Fuel enters the boiler, where heat is extracted to produce steam.
- Steam passes through a turbine, generating electricity (generator).
- The condensed steam is then sent to a condenser, where it is cooled and returned to the boiler.
- The flue gas from the boiler is cleaned through SCR-DeNOx, ESP, and FGD processes.
- The cleaned flue gas is emitted into the atmosphere.
- Air enters the boiler to assist in the combustion process.

Additional notes:
- River Rhine is used for cooling the condenser and for destrict heat water systems in cities of Mannheim, Speyer, Heidelberg, ...

Technical details:
- SCR-DeNOx: Selective Catalytic Reduction for removing Nitrogen Oxides.
- ESP: Electrostatic Precipitator for removing dust and particles.
- FGD: Flue Gas Desulfurization for removing sulfur dioxide.

Overall, the CHP process in GKM efficiently combines the production of electricity with the generation of heat for use in nearby cities.
GKM power generation (electricity) since 1923

TWh

three-phase

single-phase current


0 2.0 4.0 6.0 8.0 10.0
Efficient generation of electricity and district heat

energy for share holders and German Railway: reliable, cost-effective and friendly to environment

50 Hz three-phase alternating current
(to the share holders of GKM AG)

RWE Generation SE (40 %)
EnBW AG (32 %)
MVV RHE GmbH (28 %)

16.7 Hz single-phase alternating current

DB Energie GmbH
(German Railway)

District heat
(hot water)

MVV RHE GmbH
Mannheim
GKM plant in 2016

GKM plant: installed capacity: $2.146 \text{ MW}_{el} \ (\text{units} \ 6,7,8,9)$

- 2015: 911 MWe
- 1983: 475 MWe
- 1993: 480 MWe
- 1954: 1993 MWe
- 1962: 1993 MWe
- 1966: 2015 MWe
- 1970: 2015 MWe
- 1973: 2000 MWe
- 1975/2005: 280 MWe

- Blue: Start up year
- Orange: Gross Capacity in MW
- Gray: Shut-down (decommissioned)
GKM plant overview

<table>
<thead>
<tr>
<th>Year</th>
<th>Unit</th>
<th>Capacity</th>
<th>Commissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975/2005</td>
<td>Unit 6</td>
<td>280 MW</td>
<td>Closed 1993</td>
</tr>
<tr>
<td>1993</td>
<td>Unit 8</td>
<td>480 MW</td>
<td>Closed 2015</td>
</tr>
<tr>
<td>1983</td>
<td>Unit 7</td>
<td>475 MW</td>
<td>Closed 2000</td>
</tr>
<tr>
<td>2015</td>
<td>Unit 9</td>
<td>911 MW</td>
<td></td>
</tr>
</tbody>
</table>

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K 20
- 290/58 bar
- 100 MW Railway power
- 500 MW District heat

K 18
- DH storage
- 250 MW, 20 bar, 1,500 MWth
- 250 MW, 90/20 bar

K 19
- 200 MW
- 75 MW
- 233 MWth, District heat

K 17
- 180/20 bar
- 54 MW
- 80 MW
- 20 bar steam collecting track

Steam generator
Topping turbines
Secondary turbines
Process steam

---
Flow sheet of GKM unit 6

- Stack
- Limestone
- Water
- Gypsum
- FGD (Desulphurisation)
- ESP (Fly ash separation)
- Catalyst (DeNO<sub>x</sub>)
- Air pre-heater
- Coal mill
- Combustion air
- Coal
- Ammonia water
- Fly ash
- Water
- Gypsum
- Condensation turbine (e.g., Turbine 17)
- Cooling water from the Rhine
- District-heating turbine 21
- Condenser
- 20 bar Steam header
- 530 °C
- Condensate
- distric heat system (Mannheim, Heidelberg, Speyer)
New unit 9

Energy for Mannheim and the Region
net efficiency of coal-fired power stations

- Worldwide: 30%
- Europe: 35%
- Germany: 38%
- GKM unit 9 (ultra super critical): 46.4%
- Fuel utilization efficiency unit 9 with CHP: 70%
Unit 9 – contribution to CO₂-reduction

CO₂-emissions of old and new bituminous coal-fired power stations

new unit 9
essential contribution to reduce CO₂-emissions in Germany

- Reduction 1 Mio. t CO₂ p.a.
- Reduction 1.3 Mio. t CO₂ p.a.

traditional coal-fired power stations in Germany

unit 9

unit 9 with CHP
# Unit 9

## Facts and figures

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commissioning / start of commercial operation</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; May 2015</td>
</tr>
<tr>
<td>Investment volume</td>
<td>1.2 bil. €</td>
</tr>
<tr>
<td>Gross output</td>
<td>911 MW&lt;sub&gt;el&lt;/sub&gt;</td>
</tr>
<tr>
<td>Electrical net efficiency</td>
<td>46.4 %</td>
</tr>
<tr>
<td>District heat generation with CHP</td>
<td>500 MW&lt;sub&gt;th&lt;/sub&gt;</td>
</tr>
<tr>
<td>Fuel utilization for CHP</td>
<td>70 %</td>
</tr>
<tr>
<td>Railway electricity (16.7 Hz) (per transverter)</td>
<td>100 MW</td>
</tr>
</tbody>
</table>
Boiler of unit 9 / SCR DeNOx / air preheater

**Design data**

- **Life steam flow**: 663 kg/s
- **Life steam temperature**: 600 °C
- **Life steam pressure**: 290 bar
- **Reheat steam temperature**: 610 °C
- **Reheat steam pressure**: 58 bar
- **Feedwater temperature**: 309 °C
- **Condenser pressure**: 31 mbar
- **Preheater**: 9 stages (6 LP 3 HP)
- **Bowl mills**: 4 x 25%
- **Coal amount**: 240 t/h
Boiler unit 9 / material concept / heating surfaces

Heating surfaces

- 16 Mo 3
- 13 CrMo 4-5
- 7 CrMoVTiB 10-10
- 10 CrMo 9-10
- X 10 CrMoVNb 9-1
- VM12-SHC
- Super 304 H
  - Shot blasted
- HR3C
combined heat and power unit 9 (CHP)
Unit 9
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Electricity generation / actual situation in Germany (example)

- **fluctuating generation of renewable energies (RES)** here wind and solar (PV)
- remarkable **export of electricity from Germany to neighbour-countries** during high generation of wind- and solar-power („surplus/excess energy“)
Electricity generation in Germany since 2010

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
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<tr>
<td>Others</td>
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<tr>
<td>Natural gas</td>
<td></td>
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<tr>
<td>Renewables</td>
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<tr>
<td>Lignite</td>
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<tr>
<td>-bituminous coal</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Nuclear</td>
<td></td>
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</tbody>
</table>

Electricity generation in Germany [TWh]

- 2010: 605
- 2011: 612
- 2012: 617
- 2013: 629
- 2014: 610
- 2015: 647

Source: Amprion GmbH
RES*: installed capacity und generation in Germany since 2011 (here: wind and solar power)

*RES: renewable energies
here: wind and solar (= photovoltaic PV)

max. RES: 47.634 MW
Wind: 34.637 MW
PV: 12.609 MW
ca. 62% (30.03.2015)

min. RES: 118 MW
Wind: 118 MW
PV: 0 MW
ca. 0,2% (19.11.2014)

source: Amprion GmbH
Development of EEX-prices vs. RES generation in Germany since 2011

- RES generation (per h)
- EEX spot price (per h)
- RES generation / trend line
- EEX spot price / trend line

high RES generation

negative EEX-prices: up to -240€/MWh

date: Christmas 2012

source: Amprion GmbH
EEX-price 2015 for electricity (hourly) in Germany (wholesale / spot market)

graph showing EEX price €/MWh from 01.01.2015 to 03.12.2015

actual EEX price
variable costs bitum.
coal Power Plant
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GKM plant / daily operation in 2007 vs. today

GKM Operation in 2007

Wednesday, March 21, 2007

and today (planned and real output)

Monday, March 16, 2015

MW

real output

planned output („day ahead“)

generation of unit 9

today’s requirements in electricity market mean high demands on equipment and personnel in GKM: high flexibility in load changes and timing
Full-Load-Operation-Hours of unit 6 (decreasing operation time because of increasing generation of RES in Germany)

unit 6 start ups per year actually: about 200
unit 8 / load diagram (typical example)

load of unit 8   February 17, 2014

begin start up (hot)
typical start up diagrams of unit 8

start up diagrams of unit 8 (cold-, warm-, hot-start)

- hot < 8 h
- warm > 8 h < 48 h
- cold > 48 h start

40 Min 55 Min 70 Min

105 minutes 150 minutes 190 minutes

started diagrams of unit 8 (cold-, warm-, hot-start)

life steam flow [%]

0 20 40 60 80 100 120

time [minutes]

0 50 100 150 200 250

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GKM / reduction of minimum load 2005 vs. today

stable minimum load GKM plant

Minimum load [MW]

2005
2006 -12
2013
2014
2015

unit 3/4
from 2006 unit 6 (before unit 7)
Mannheim district heat system / GKM CHP Plant
GKM Plant / district heat system until 2013

GKM „2-units-operation“ necessary at minimum load because of need for secure supply of district heat system (until end of 2013)

- Unit 7
- Unit 8
- Unit 3
- Unit 4
- Unit 6

20 bar / 300 °C steam system

- Process steam
- Condensing turbines 50 Hz / 16.7 Hz
- District heat turbines M20/21

20 bar / 530 °C steam system

- Condensing turbines 50 Hz / 16.7 Hz
- Auxiliary boilers

District heat system (Mannheim, Heidelberg, Speyer)
task / functions of new GKM heat storage system

Load demands on CHP Plant GKM
• 50 Hz Electricity Generation for RWE, EnBW, MVV
• 16.7 Hz Electricity Generation for DB Energie
• Distric Heat Generation and **secure supply** of Mannheim, Heidelberg and Speyer

Situation at German Electricity Market
• GKM Plant Load corresponding to EEX Prices (Spot-Market „day-ahead and intraday“): volatile and often not fitting to district heat energy consumption

Functions of new heat storage system in GKM
• in times of low EEX Prices the GKM Electricity Generation must be as low as possible (minimum technical load)
• **the new heat storage tank enables GKM to operate only 1 unit during minimum load (instead of 2 units before)**
• during minimum load the heat content in the tank is sufficient to supply the district heat nets at least for 2 hours
• additionally the heat storage tank is used to optimize the plant operation depending on EEX Prices (e.g. **charging at night, discharging by day**)

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GKM Plant / district heat system since 2015

GKM „1-unit-operation“ possible at minimum load / if district heat load < 250 MW (since heat storage system finished: end of 2013)

new heat storage system enables GKM CHP plant to reduce the minimum load significantly
### technical data GKM heat storage system

**Heat storage tank ("system Dr. Hedbäck")**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter tank</td>
<td>m</td>
<td>40</td>
</tr>
<tr>
<td>Cylindrical height tank</td>
<td>m</td>
<td>36</td>
</tr>
<tr>
<td>Storage capacity</td>
<td>m³</td>
<td>43,000</td>
</tr>
<tr>
<td>Max. flow to / from tank</td>
<td>t/h</td>
<td>6,200</td>
</tr>
<tr>
<td>Max. storage water temperature</td>
<td>°C</td>
<td>98</td>
</tr>
<tr>
<td>Effective heat storage capacity</td>
<td>MWh</td>
<td>1,500</td>
</tr>
<tr>
<td>Max. load (water flow)</td>
<td>MW</td>
<td>250</td>
</tr>
</tbody>
</table>

Hedbäck storage system can also be used for **cold water storage**
GKM heat storage tank completed (September 2013)
operation of heat storage tank (7 days, example)

energy content [%]

- charging
- discharging

- time / date

energy content [%]

- 17.01.2014 00:00:00
- 24.01.2014 00:00:00
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Conventional Power Plants / GKM situation

Actual situation of conventional Power Plants in Germany / „Energiewende“

- increasing and high capacities of „renewables“ RES (esp. solar (PV) and wind) for electricity generation with fixed and governmental guaranteed compensation
- since more than 4 years decreasing and volatile EEX Prices

Situation at GKM

- GKM Plant load is corresponding to EEX Prices (Spot-Market „day-ahead and intraday“), production volume and operation hours of units are decreasing
- need for permanent Distric Heat Generation and secure supply
- power plants „struggle with economics“
- new heat storage system enables GKM to operate only 1 unit during minimum load (instead of 2 units before)
- significant reduction of minimum load of all GKM units and „must run“ generation
- increase of efficiency by new unit 9 and decommissioning of old units 3 and 4
- permanent measures to improve load flexibility
Technical quality and reliability

Basic needs for Conventional Power Plants

- Good and proven **design** in detail
- Proper **equipment** / components
- Adequate **erection** and installation
- Realization of **high automatization with electronic/digital control systems** for each unit and the whole plant
- **Commissioning by qualified teams** including checks of all systems / functions
- **Process optimization** under real operational conditions, esp.
  - Training of start up (cold, warm, hot) and stops of the units
  - Load changes in the complete range (min. to max. load, quick start and stop)
  - Tests of all types of failures
  - Defined conditions during time when „plant is not in operation“
- **Highly qualified and motivated staff for operations, maintainance, optimization** and different supporting tasks (purchase, finances, contracts, insurance, risk-management, personnel, ….)
Operations and maintenance aspects

- realistic, professional planning of power plant operation and maintenance including outages/overhauls
- qualified dispatching (load/generation planning) „day ahead“, „intraday“, redispatch measures,… till the „last moment“ (= time of production)
- highest flexibility to fulfill the needed functions („market driven“)

Criteria / Monitoring

- high efficiency / low energy losses
- low emissions (i.e. good work in „Environmental-Health-Safety“ fields)
- secure, good technical functions, high reliability in operations
- availability to the right time (looking after the „market situation“: esp. EEX prices and customer´s demands)
- economic aspects (remaining competitive)
Thank you for your attention.
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