Energy

Status Quo and Future Prospects of Hydro Power in Germany

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content

- historical development
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historical development
ancient civilizations on the Indus river (Indian subcontinent), in China, Egypt and Mesopotamia had incredible knowledge in hydraulic engineering. They utilized water wheels for the first time to irrigate agricultural areas and to supply potable water to populated areas. These water wheels had the daily capacity equal to 15 – 20 workers day-work.

From Roman times until the medieval ages various new application areas had been developed for hydro power machinery: corn was milled on river boat based mills, metals were processed in hammer mills and saw mills made the production of wood products easier. In mines ground water pumps and elevators were running on hydro power.
principle of an undershot water wheel
principle of an overshot water wheel
In Germany hydro power accounts for approx. 4% of the power production, worldwide it’s 18%. A moderate expansion, also in view of the protection of the natural habitat, is possible.

especially in Southern Germany, as coal was not available, hydro power generated 70% of the necessary power. Due to the competition of cheap fossil energy about 50,000 small hydro plants were mothballed until the 1980ies. Large plants stayed in operation.
since 1990 Germany started a turnaround for smaller plants due to higher feed in tariffs for renewable energy and other supporting programs.

In many areas weir systems and canals were still existing which could be utilized – if compatible with environmental protection - for the reactivation of hydro power plants. Many operating plants were modernized due to the better feed-in tariff system.
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technology
water wheels are utilized when water head is below 10 m

today hydro power plants almost exclusively use turbines; three different types dominate the market: Kaplan-, Francis- and Pelton turbine. Various alternative layouts exist based on these basic models

hydro power plants are classified according to different criteria: if the mode of operation is important we differentiate between run-of-river power stations, reservoir power stations (e.g. dams) and pump storage power stations. The different head divides into low pressure (1 - 20 m), medium pressure (20 – 100 m) and high pressure facilities (> 100 m) and the different capacities into small power (< 1 MW), medium power (1 - 100 MW) and large power plants (> 100 MW). The electrical output depends the hydraulic capacity and the efficiency of turbine and generator set. During one year small plants run 4,000 – 5,000 and large plants 4,500 – 5,700 hours (peak load).
technology: the Francis turbine

The Francis turbine operates under high pressure. The blades of the idler are adjustable. Fields of application: 20 – 700 meter of incline, flow rate 0.3 – 1,000 m$^3$/s, dams
The Kaplan turbine operates under high pressure. The guide vain apparatus and the rotor blades are adjustable. Fields of application: 2 – 60 meter of incline, flow rate 4 – 2,000 m³/s, rivers.
The Pelton turbine operates under normal ambient pressure. The water flows (blasts) through one or various inlets onto the bucket blades of the runner. Fields of application: 150 – 2,000 meter of incline, flow rate 0.02 – 70 m³/s, storage power stations in high mountains.
## Technological Strengths and Weaknesses of Water Wheels and Turbines

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<th>Water Wheels</th>
<th>Water Turbines</th>
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<td><strong>Strengths</strong></td>
<td>need relatively low incline and low water quantities, not sensitive to volatile water quantities and flotsam, few hydraulic engineering measures necessary</td>
<td>high speed (partially no transmission necessary), efficiency &gt; 90%, for every kind of head turbines are available</td>
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<tr>
<td><strong>Weaknesses</strong></td>
<td>low speed (3 – 5 U/min.), needs gear for transmission, larger space required, efficiency max. 80%, for large plants not advisable</td>
<td>need relatively high incline, sensitive against volatile water quantities and flotsam, extensive hydraulic engineering measures necessary</td>
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scheme of a run-of-river power station with a Kaplan turbine

- head waters
- water intake
- Generator
- Kaplan-Turbine
- water reaches
- water outlet
scheme of a reservoir power station with a Pelton turbine

storage lake
pressure tunnel
concrete wall
pressure pipe
power house
**selected environmental impacts of small hydro power stations**

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<th>positive</th>
<th>negative</th>
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<td>CO(_2) neutral power generation with positive impact on climate protection</td>
<td>migration of fish and other animals are constrained or even injured during turbine flow, natural habitat is reduced</td>
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<td>oxygen content in water reaches goes up</td>
<td>oxygen content in head waters is reduced and sediments build up</td>
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<td>part of municipal waste is removed from the rivers</td>
<td>important components for the ecosystems (wood, leaves) are removed from the water</td>
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<td>water flow after precipitation is slowed down</td>
<td>natural floods are constrained and access to ground water aggravated</td>
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status quo
Germany had about 5,500 small hydro power plants (< 1 MW) by the end of 2002, which produced approx. 8% of the hydro power and 400 medium and large size installations. Small plants are in the possession of private individuals, larger plants are owned by the large utility companies.

Installed total capacity was 4,600 MW in 2003 and produced approx. 20.4 billion kWh (source: BMU). This value may vary due to the changing precipitation (in rain rich 2004 the total power produced was 24 billion kWh). Regional focus are the southern states of Germany, low mountain ranges and larger rivers (e.g. Rhine, Donau, Mosel, Neckar and Weser).
plants below 1,000 kW capacity are regarded in Germany as small hydro power plants. Mainly those plants are in historic places where mills were operating in earlier times. For the yearly capacity turndown, the permanent capacity with volatile water inlet, is more important than peak performance during ‘normal’ water. Most small hydro power plants run fully automatic (e.g. removal of the rakings) or via remote monitoring. Capex for a plant is 8,500 – 10,000 EUR/kW (source: BMU).
run-of-river power plants at rivers utilize large quantities of water with a low water head. During the electrification and industrialization of Germany during the 20th century various barrages in combination with run-of-river plants were built for the development of the shipping industry. Due to their continuous operation and power production they are utilized for base load. RWE Power has modernized 10 plants on the Mosel river during 1995 – 2003 to raise efficiency and power production and lower Opex.
reservoir power stations (mostly dams) with capacities of > 1,000 MW and efficiencies of approx. 75% collect water during the months of high precipitation up to their maximum capacity. Whenever necessary the water can be utilized to produce power, when the grid has a high demand in power consumption (peak load power plants). The stored water is also used to regulate the water level in rivers and for the supply of potable water, power production is not the only purpose. A special form are pump storage power plants. When power is available in excess (and cheap) water is pumped from a lower basin to a higher basin. When power demand rises (and the kWh is more expensive) the water produces power using the Francis turbines.
load distribution

- **base load**
- **mid-load**
- **peak load**

http://timbeil.blogspot.com
creeks and rivers are a central element of the natural habitat and have to be specially protected. Natural streams and watercourses are not only the natural environment for fish and water plants but also for birds, amphibians and insects. Alluvial forests and the ground water balance depend on them. In Germany only 20% can be regarded as semi-natural. They have to be protected and are not to be utilized for hydro power.

water bodies which have harmed earlier due to hydraulic engineering works or sewage disposal, a utilization of hydro power may have positive ecological effects
hydro power plants also have an impact on water ecology. During the approval process – depending on the local conditions – the emission free production of power has to be balanced against the problematic impact on the natural habitat of the watercourses. During the environmental impact study the following criteria are important: how can we secure that fish and other animals can migrate in face of weir systems and barrages? How much water has to stay as a minimum requirement in the river? What is the impact of the hydro power plant on head water and water reaches?
In most cases during the approval process it is possible to balance the above problems and to reach good compromise between hydro power production and the protection of nature. Building fish passes, obligatory minimum water level requirements and many more provisions the ecological balance can be improved. Within the overall ecological balance the modernization of existing plants and the reactivation of existing weir systems and canals, at ancient mill locations, have the best performance.
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future prospects
Worldwide, there is still enormous potential for hydropower, in particular in Asia, South America and Africa

Source: VDMA (German Engineering Federation)