LOW HEAD HYDRO TURBINES

Joule Centre Annual Conference
Small Hydro Power Schemes in the North West of England: Overcoming the Barriers
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Agenda

- Definition - low head (application range)
- Special aspects of low head applications
- Risks of low head applications
- Possible turbine types for low head application
- Fish-friendly turbine concept – some aspects
- Examples and references of low head applications
- Summary
Definition - low head (application range)

- Heads - approx. 2 to 35 m
- Flows - approx. 0.3 to 100 m³/s

- General turbine types
  - Axial turbine
  - OR
  - Radial turbine – Francis
    (for “higher” low heads)
Special aspects of low head applications

- „Flat“ landscapes
- often running river plant
- very often a dam / weir needed
- „polluted“ water (e.g. grass, algea, „garbage“, …)
- old mill places or similar
- generally low speed turbines > „expensive“ generators if direct-coupled
- ecological aspects > e.g. fish friendliness
  - Fish ladder
  - fish-friendly turbine concept
Risks of low head applications

- the lower the head the more important the design of the intake & draft tube side is
  - „incorrect“ design can destroy fairly easily the net head and performance
  - how (flow, velocity) the water streams in and out the turbine is essential
    - use an experienced consultant and turbine supplier
    - investigate before concreting
Risks of low head applications

- power loss due to algae and grass
  - the smaller the runner diameter the higher the risk
    - use a good trash rake (and cleaner)
    - can be optimised with a „flush“-control
Possible turbine types for low head application - AXIAL

- Axial type turbines
  - heads approx. 2 to 35 m
  - flows approx. 3 to 100 m³/s
  - turbine speed varies approx. 100 … 500 rpm (low speed)
  - double or single-regulated
  - mostly Kaplan runner (3 to 6 blades)
  - generator direct-coupled or with a gear box
  - vertical, horizontal or slant arrangement
  - different runner diameters
Possible turbine types for low head application - AXIAL

- Belt Drive Bulb Turbine (BDB)  
  \( Q \approx 6 \ldots 25 \text{m}^3/\text{s} \quad H \approx 2 \ldots 4 \text{m} \)

- Bevel Gear Bulb Turbine (BGB)  
  \( Q \approx 3 \ldots 45 \text{m}^3/\text{s} \quad H \approx 2 \ldots 12 \text{m} \)
Possible turbine types for low head application - AXIAL

- Compact Axial Kaplan Turbine (CAK)  
  \[ Q \sim 6 \ldots 60 \text{m}^3/\text{s} \quad H \sim 2 \ldots 12 \text{m} \]

- PIT Turbine (PIT)  
  \[ Q \sim 20\ldots 100 \text{m}^3/\text{s} \quad H \sim 2 \ldots 12 \text{m} \]
Possible turbine types for low head application - AXIAL

- Compact Axial Turbine (CAT)
  - $Q \sim 3 \ldots 68\,\text{m}^3/\text{s}$
  - $H \sim 15 \ldots 35\,\text{m}$

- Compact S-type Turbine (STP)
  - $Q \sim 3 \ldots 65\,\text{m}^3/\text{s}$
  - $H \sim 15 \ldots 25\,\text{m}$
Possible turbine types for low head application - AXIAL

- Ecobulb-turbines (with direct coupled permanent magnet generator)

- Compact Bulb Turbine (with direct coupled synchronous generator)
Possible turbine types for low head application - AXIAL

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- A solution for low head sites with existing dam and weir structures
- Available head from 3 m up to 10 m
- Modules of propeller turbine units (Bulb type)
Fish-friendly turbine concept (axial) – some aspects

- Type – Bulb turbine
- low speed
- „large“ runner diameters
Fish-friendly turbine concept – some aspects

- reduced number of runner blades 3 instead of 4 (~50% more space)
- reduced hub size
- reduced blade length (~20% reduction)
### Examples and references of low head applications

<table>
<thead>
<tr>
<th>Plant</th>
<th>Country</th>
<th>No</th>
<th>Type</th>
<th>Runner-Ø [mm]</th>
<th>Output [MW/turb.]</th>
<th>Head [m]</th>
<th>Speed [rpm]</th>
<th>Year</th>
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<td>Penig</td>
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<td>Belt Drive Bulb</td>
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Examples and references of low head applications

AND IN UNITED KINGDOM?

- since 1999: 10 different Axial turbines from 0.5 to 4.2 MW
- since 1912: 13 Francis turbines from 0.1 to 7.5 MW (heads below 35m)
- since 1906: 28 Pelton turbines from 0.6 to 106 MW (not low head)
Summary – low head turbine application

- „low“ heads roughly 2 to 35m
- large range of turbine products available (axial type and radial type)
- Often low speed turbines (approx. 100 to 500 rpm)
- low speed direct coupled generator > good but expensive
- Gear box can make a project feasible > reduction generator investment
- „Fish friendly“ turbine concepts
- risks
  - Power loss due to grass or algae
  - Incorrect Design on the intake/drafttube side – „high“ head loss