Session A5- Downstream fish passage via fish friendly turbine

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DOWNSTREAM PASSAGE THROUGH A FISH FRIENDLY TURBINE

National Conference on Engineering & Ecohydrology for Fish Passage
June 27-29, 2011 • University of Massachusetts Amherst

Greg Allen, Steve Amaral, Norman Perkins, and George Hecker

Doug Dixon

ALDEN
Solving flow problems since 1894

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Jason Foust

VOITH HYDRO POWER GENERATION
Downstream Passage via a Fish Friendly Turbine

- Introduction
- Background (hydro)
- New technology
- Turbine design
- Potential Application
- Relative costs
- Summary
Why is hydropower important?

- Clean renewable power
- Largest resource of renewable energy (35% of total renewable energy supply in U.S.)
- Load stabilization – high capacity factor
- Vital to reduce nations carbon emissions
- Untapped capacity ~ 300,000 MW
- EPRI estimates 14,000 MW developed by 2025
Why is hydropower important?

BACKGROUND
Hydropower’s Role

U.S. Energy Consumption by Energy Source, 2009

Total = 94.578 Quadrillion Btu

- Petroleum 37%
- Natural Gas 25%
- Coal 21%
- Nuclear Electric Power 9%
- Renewable Energy 8%

Total = 7.744 Quadrillion Btu

- Hydropower 35%
- Wood 24%
- Biofuels 20%
- Wind 9%
- Geothermal 5%
- Biomass waste 6%
- Solar 1%

Note: Sum of components may not equal 100% due to independent rounding.
Environmental mitigation – dominant theme

- Projects built w/o appreciation of impacts
- 5 to 30% mortality for fish passing through turbines
- Restoration of diadromous and endangered species
- Requires fish passage facilities and/or modifications/restrictions to operation
- Overall reduction in energy output (kwhrs)
- Energy reductions offset by fossil projects
Puget Sound Energy’s $53 million “gulper” for protecting downstream migrating salmon
Hydropower implications

- Costly fish diversion and exclusion structures (bar rack, louvers, bypasses)
- Bypass flows (2% to 5% of station capacity)
- Minimum spillway releases
- Effectiveness varies
- Generation restrictions
A fish friendly turbine could be....

- Available as a bypass
  - Increase bypass volume – 20 to 100% of station flow (versus 2 to 5% at most sites)
  - Increase effectiveness of fish passage facilities
- Minimum flow releases
- New low impact developments
15 yrs of Research and Development funded by DOE and EPRI

Pilot scale test - over 40,000 fish (most extensive direct turbine survival study ever conducted)
What makes it fish friendly?

- Bigger
- Slower
- Few blades
- No gaps
- Big blunt leading edge
- Blunt leading edges on vanes and gates
- Biological design criteria – shear, pressure, velocity
POTENTIAL APPLICATION

- Theoretical survival predictions for the Alden turbine
  - Hadley Falls (Connecticut River, MA)
  - School Street (Mohawk River, NY)
  - Pébernat (Garonne River, France)
POTENTIAL APPLICATION
School Street Hydroelectric Project

Head: 92 ft
Flow: 1,500 cfs
Diameter: 12.7 ft
Speed: 120 rpm
90% of fish entrained at hydro projects are < 200 mm

83.5% for a comparable Kaplan unit

> 90% of fish entrained at hydro projects are < 200 mm

School Street Hydroelectric Project

Head: 92 ft
Flow: 1,500 cfs
Diameter: 12.7 ft
Speed: 120 rpm
POTENTIAL APPLICATION

Hadley Falls Hydroelectric Project

Head: 35 ft
Flow: 1,200 cfs
Diameter: 13 ft
Speed: 72 rpm
POTENTIAL APPLICATION

Hadley Falls Hydroelectric Project

- Head: 35 ft
- Flow: 1,200 cfs
- Diameter: 13 ft
- Speed: 72 rpm

Turbine Passage Survival (%)

Fish Length (mm)
POTENTIAL APPLICATION
Pébernat Hydroelectric Project

Head: 66 ft
Flow: 1,267 cfs
Diameter: 10.6 ft
Speed: 101 rpm
POTENTIAL APPLICATION
Pébernat Hydroelectric Project

- Head: 66 ft
- Flow: 1,267 cfs
- Diameter: 10.6 ft
- Speed: 101 rpm

- Turbine Passage Survival: 98.1%
## RELATIVE COSTS

<table>
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<tr>
<th></th>
<th>Alden Turbine</th>
<th>Conventional Francis</th>
<th>Conventional Kaplan</th>
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<tr>
<td><strong>SIZING</strong></td>
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<td>Diameter (mm)</td>
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<td>2510</td>
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<td>Power (MW)</td>
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<td><strong>COSTING</strong></td>
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<td>Generator</td>
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<td>Installation and Comm.</td>
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<td>Automation/ BoP</td>
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<td>Relative Costs</td>
<td>2.3</td>
<td>1.65</td>
<td>1.7</td>
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<td><strong>Premium for Alden</strong></td>
<td>39%</td>
<td></td>
<td>35%</td>
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</table>
Benefits offsetting premium

- Less powerhouse excavation (higher turbine setting)
- Generating with bypass flow (previously wasted/spilled)
- Avoid O&M and capital costs for bypass system

True costs comparison

Alden unit $\leq$ Francis or Kaplan units
SUMMARY

- High survival estimates > 98%
- Comparable performance ~ 94% efficiency
- Provides downstream passage while generating power
- Reduces need for costly fish passage facilities
- Next step – field demonstration site
  - School Street
  - Pébernat
- Verify field performance and gain industry and resource agency acceptance
QUESTIONS?

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