Small Scale Hydro Power Systems

Practicalities Workshop

Matthew Rhodes
Managing Director
Agenda

- Site assessment
- Design
- Operations and maintenance
- Concluding project tips
And all projects start from understanding the potential of your site

Power = flow x head x specific weight of water

$P = Q \cdot H \cdot \gamma$

What is the flow?

What is the head?

...plus...am I going to hit any obvious problems with neighbours, regulators, planners, electricity companies...?
You should then be planning for a structured process that balances risk/spend with realistic progress.
There is good data on flows available – but be aware this is a **statistical** exercise

Are there any gauging stations close by?
Check http://www.nerc-wallingford.ac.uk/ih/nrfa/station_summaries/map.html

Beware natural springs and sink holes using gauging station data
Wallingford can give you a catchment-based flow estimate using their LowFlow software.
Flow analysis can be validated by onsite methods

Weirs are the best method for long term measurement
Head is easier to measure and you can use standard surveying tools.
Check for restrictions in head and tail race

Need to ensure head and tail race can cope with volume of flow
Electrical connection

Many hydro systems use 3 phase induction motors
Some hydro systems use single phase permanent magnet motors
Batteries
Grid connection (G83/G59)
Flooding

Engage with DNO as soon as possible - they can help establish total costs
Depleted reach
Fish passes
Abstraction licence
Impoundment licence
Land drainage consent
Salmon and freshwater fisheries approval

Engage with EA as soon as possible you will have to comply with them
Typical 4-6 months from pre-application to site visit
Other issues to watch for

- Increased risk of flooding upstream
- Planning consent (new structures within 7m of watercourse)
- Noise – adjacent properties (perceptions not necessarily reality)
- Visual impact (e.g., flow depletion over weirs)
- Site access
- Scope for onsite use of power (can affect economics)
- Land ownership (shared ownership or boundary issues)
From your flow assessment you should end up with something like this....

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean flow (l/s)</td>
<td>238</td>
<td>195</td>
<td>176</td>
<td>149</td>
<td>120</td>
<td>100</td>
<td>84</td>
<td>81</td>
<td>86</td>
<td>127</td>
<td>151</td>
<td>187</td>
</tr>
<tr>
<td>Max (Q5) flow (l/s)</td>
<td>625</td>
<td>488</td>
<td>409</td>
<td>336</td>
<td>250</td>
<td>194</td>
<td>152</td>
<td>162</td>
<td>197</td>
<td>378</td>
<td>425</td>
<td>526</td>
</tr>
<tr>
<td>Min (Q95) flow (l/s)</td>
<td>82</td>
<td>77</td>
<td>79</td>
<td>67</td>
<td>61</td>
<td>53</td>
<td>48</td>
<td>45</td>
<td>45</td>
<td>53</td>
<td>61</td>
<td>71</td>
</tr>
</tbody>
</table>

Modest stream
A flow duration curve is used to simplify the statistics and give us a common language ($Q_{xx}$).

For 95% of the year there will be at least 760 l/s flowing in this stream.
We can use flow statistics to get to a starting point for turbine sizing and optimal flow abstraction by assuming fixed flow turbine(s)

- Tabular method of turbine sizing
- Once you’ve established a basic starting point, you’re ready to engage with manufacturers and look at specific efficiency curves and turbine selection – this will usually involve trade offs
Turbine designs are optimised for different flow/head combinations.

The basic science is simple: If you rotate a coil in a magnetic field (or vice versa) you generate electricity.

All turbines are machines for turning linear energy into rotating energy.
Crossflow
Pelton wheel and turgo
Archimedes screw

Fish can swim through happily.
Waterwheels are possible but less efficient

The gearbox can be the major cost

They can be monsters!
For many systems it is worth investing in multiple turbines and more or less sophisticated controls

Twin turbines which operate singly or together depending on incoming flow (electronic control)

An elegant mechanical control system diverts flow across 33/66/100% of the runner surface as the incoming flow rises
Turbine house configuration – you need to manage risks of electrical equipment getting wet
Penstock design must be optimised to minimise head loss

The head loss at the penstock (HL2) can be calculated by the following equations.

\[ HL2 = hf + he + hv + ho \]

where,

- \( hf \): Frictional loss at penstock
- \( he \): Inlet loss
- \( hv \): Valve loss
- \( ho \): Other losses (Bend losses, loss on changes in cross sectional area and others)

The rules are simple—straight as possible, round sweeps, and steady elevation declines.
Open channels cut the costs of pipework but you can only take the head from the end of the channel. The roughness and shape of the channel will affect how much flow you’ll get.
Head races must be designed for effective maintenance – it’s all about supplying consistent, designed flows of clean water to the turbine
Screens are critical for both system protection (trash) and wildlife protection.

There are many designs – you need to consider maintenance and head loss.

How do we clean a screen here?

Where will this go?
The tail race is important because if flow can’t get out it won’t come in....

..also watch for bank or bed erosion and design this out!
Electrical connections are physically simple, but above 5kW you hit harder regulations, and above 50kW serious design checks will be required.

G83 and G59
Local grid capacity and protection issues
Maintenance and operations
Maintenance – requirements vary by turbine type and manufacturer

Penstocks also benefit from regular cleaning
Some machines and makes are more durable than others
The biggest maintenance issue can be trash screen cleaning

In theory self-cleaning – but periodic checks are probably a good idea.
Overall project tips
Use a structured approach and have realistic expectations

- **Resource assessment**: Enough info to decide whether to spend any money at all ("size of the prize")
- **Feasibility**: Enough info to enable informed engagement with stakeholders and regulators and suppliers (and to start spending painful amounts of money)
- **Design**: Enough info to know what the costs and benefits should be (subject to license conditions), to secure formal approvals, and to remove doubts of any hardened objectors (may be subject to technical/cost-relevant negotiation)
- **Installation**: Final bills and income stream!
In practice, you can quickly get into an infinite loop – Beware!

Flooding
Flow access
Environment issues
Civil costs
Power connection
Fish/trash management

All require specialist assessment and input from (non-hydro) experts who will need a proper briefing

To produce the design you need to have feedback on specific issues.....

To give them a proper briefing requires a design for them to assess

BEWARE THE CIRCLE OF DEATH!
As soon as you engage a manufacturer or installer you are likely to be making implicit technical choices – so plan to do this at the right point. Recommended focus of partner engagement to secure optimum value.
A wide range of specialist help is available (but is not always easy to engage)

**Installers**
- Derwent Hydro (>3m head)
- GreenEarth Energy
- Hydrogeneration (Segen)

**Consultants**
- Encraft
- Dulas
  (Segen, MannPower)
- (Derwent)

**Manufacturers**
- Gilbert Gilkes and Gordon (to 10MW)
- Valley Hydro
- Ossberger
- New Mills
- Freeflow (micro/pico)
- Ampair/Boost (micro/pico)
- MannPower (Distributor/consultant)
- Clink
- Oy Waterturbines

**Associations**
- British Hydropower Association
- Mendip Power Group
- South Somerset Hydropower Group
- Herefordshire Hydro

It pays to know your stuff and do things in the right order
## An actual budget – note line headings

<table>
<thead>
<tr>
<th>Activity</th>
<th>Budget cost</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminary feasibility study</td>
<td>£ 950</td>
<td>Complete</td>
</tr>
<tr>
<td>Detailed design</td>
<td>£ 5 000</td>
<td>Complete</td>
</tr>
<tr>
<td>Licenses and permits</td>
<td>£ 2 000</td>
<td></td>
</tr>
<tr>
<td>Project management</td>
<td>£ 3 000</td>
<td></td>
</tr>
<tr>
<td>Turbines, generator, controls and pipework</td>
<td>£ 26,000</td>
<td>Including trash screen</td>
</tr>
<tr>
<td>Installation and commissioning</td>
<td>£ 11 000</td>
<td></td>
</tr>
<tr>
<td>Civil engineering</td>
<td>£ 6 000</td>
<td>Free onsite labour</td>
</tr>
<tr>
<td>Contingency</td>
<td>£ 5 000</td>
<td>Exchange rates, design mods</td>
</tr>
<tr>
<td>Grants</td>
<td>(£ 2 500)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>£ 56 450</strong></td>
<td>Including estimated civil costs</td>
</tr>
<tr>
<td>Operations (annual)</td>
<td>£ 850</td>
<td>Allow for 10% increase per year</td>
</tr>
</tbody>
</table>

5kW scheme – good existing infrastructure, no EA issues
Wrap up

- Hydro projects require a mix of traditional civil, mechanical and electrical construction and contracting skills
  - Plus you need MCS certification for FITs
- Maintenance requirements vary by manufacturer and turbine type
  - you can get very low maintenance crossflows (but this costs more)
  - you always need a maintenance strategy for the trash screen, channels, and penstock, even with a low maintenance turbine
- High head (low flow) sites will always be easier than low head
- Don’t go into denial about the critical importance of regulators (moaning is OK!)
- Engage with the right specialists *at the right time*
- It’s worth it!
Matthew Rhodes
Managing Director
matthew.rhodes@encraft.co.uk

+44 (0) 1926 312159

6b Park Street
Leamington Spa
CV32 4QN