CASE STUDY: DEVELOPMENT OF LOW HEAD TURBINES TO ADDRESS THE MICRO HYDROPOWER MARKET

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INTRODUCTION

Ministry of New and Renewable Energy (India) has been vested with the responsibility of developing Small Hydro Power (SHP) projects up to 25 MW station capacities. The estimated potential for power generation in the country from such plants is about 20,000 MW. Most of the potential is in Himalayan States as river-based projects and in other States on irrigation canals. The SHP programme is now essentially private investment driven. The Ministry’s aim is that at least 50% of the potential in the country is harnessed in the next 10 years.

Globally, the SHP potential is estimated at over 750,000 MW with the USA & Canada alone accounting for 100,000 MW.

HYDRO POWER PROJECT CLASSIFICATION

Hydro power projects are generally categorized in two segments i.e. small and large hydro. In India, hydro projects up to 25 MW station capacities have been categorized as Small Hydro Power (SHP) projects. While Ministry of Power, Government of India is responsible for large hydro projects, the mandate for small hydro power (up to 25 MW) is given to Ministry of New and Renewable Energy. Small hydro power projects are further classified as

<table>
<thead>
<tr>
<th>Class</th>
<th>Station Capacity in kW</th>
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<tbody>
<tr>
<td>Micro Hydro</td>
<td>Up to 100</td>
</tr>
<tr>
<td>Mini Hydro</td>
<td>101 to 2000</td>
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<tr>
<td>Small Hydro</td>
<td>2001 to 25000</td>
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</table>

Projects in the Micro and Mini segments could be further subdivided into high, medium and low head sites. Various assessments conducted over the years indicate that over 2000 MW of this SHP potential lies in the low head (< 3metre) range while almost 50% of the estimated SHP potential is in the Micro and Mini Hydro segments. This paper would only address these two segments.

There are various difficulty factors that require to be addressed, for projects to be viable, sustainable and successfully commissioned. Hitherto, high costs & consequent viability concerns, long gestation periods due to delayed clearances & land acquisition and non-availability of an appropriate technology have resulted in a veritable stagnation of new projects.
Realising these constraints, it was felt appropriate to focus on developing a technology that could address these concerns and provide a viable and sustainable solution for development of Micro and Mini hydropower projects, with specific focus on low heads.

**OBJECTIVE**

- Develop a viable and sustainable technology to permit hydropower generation in the Micro and Mini segment with specific emphasis on generation at low heads
- Installation and commissioning time should be low, facilitating early generation and reduction of cost of project
- O&M costs must be reduced and manpower interventions should be low, to improve viability of smaller capacity plants
- Reduced environmental impact (relocation, rehabilitation & deforestation, marine life) and lower land acquisition
- Do away with the conventional power house concept to facilitate remote operation of the hydropower plant
- Permit operation in extreme climatic conditions without intervention

Based on this statement of purpose an appropriate “wish list” of product features was drawn up to provide a guideline for the direction of the development effort. These features would help drive the entire effort from concept to commissioning.

**TECHNOLOGY**

**Desirable Product Features**

- Product should not require assembly at site
- Turbine & generator must be integrated
- Product should be relatively maintenance free
- It should drastically cut down civil construction needs
- It must abide by the guidelines laid down by MNRE and State EDAs for subsidy support
- Minimum components and moving parts
- Composite construction for better tolerance to ambient conditions
- Installation should be relatively simple
- Maintenance interventions should be minimal and largely preventive in nature, resulting in low O&M costs
- Cost competitive
- Remote control and management should be possible

Based on desirable product features, a concept emerged that defined product features for the integrated turbine and generator, referred to as turbine generator. This would form the basis
for the entire design effort that would culminate in the hydraulic and mechanical design of the turbine generator.

THE CONCEPT – AN IN-PIPE TURBINE GENERATOR

Product Features

- Turbine integrated with a permanent magnet generator
- The Turbine is completely housed inside a pipe with flanged ends
- Depending on the available flow and head these turbines could be installed in series or in parallel
- The Turbine has minimum number of components and just one moving part (with the shaft being stationary)
- The Turbine is simple to install and maintain; low O&M cost
- Low environmental impact
- Remotely controlled operations of power plant

CONCEPT DRAWING

(a) Turbine
(b) Installation Methodology

Once the concept and base design parameters were firmed up, the hydraulic design effort commenced. Simulation of the turbine surfaces, 3-D geometry and the flow was completed using CFD. For the first trials at a head of 10 metres, the typical finding are represented below.

**CFD Validation**

CFD analysis was carried out for the In-pipe turbine for the following input head, flow, speed and mechanical power output, duty point.

Flow-464 LPS, Head- 10m, Speed-1500 rpm, Mechanical Output -40 kW
Targeted Turbine Efficiency - 84%

Findings

(a) Pressure Plot

(b) Velocity Plot
Results

Flow- 492 LPS, Head- 10m, Speed – 1500 RPM, Mechanical Output – 40.61 kW

Hydraulic efficiency - 84.22%

Standardization of design

- Turbine design standardized across a range of capacities providing substantial cost benefits
  - 25 to 100 kW – one design
  - 101 to 250 kW – one design
  - 251-750kW – one design

- Standardized designs eliminate the need for site based customization
- Standardized design & installation methodology would simplify environmental clearance & approval process
- Laboratory testing and certification made possible for Low Head High Flow (LHHF) and High Head Low Flow (HHLF) categories using the same turbine
Prototype

Test Set-up

Testing was conducted on a prototype at MANIT (Bhopal) and also at a full-fledged in-house testing facility.

These facilities have the following capabilities:

a) Mechanical power measurement
b) Electrical power measurement
c) Testing under high heads using a pump
d) Testing under static head using overhead tanks
e) Series / Parallel configuration testing
Test Set-up at Bhopal

Results for Medium Head & Low Head Turbines

In-house testing of the turbine at medium and low heads at various testing points have given the following results which corroborate the CFD findings.

a) Medium Head: Head - 10 m, Flow – 400 LPS, Speed – 800 RPM, Mechanical Output – 40.8 KW, Hydraulic Efficiency - 85.9%

b) Low Head: Head – 2 m, Flow – 230 LPS, Speed – 600 RPM, Mechanical Output – 5.9 KW, Hydraulic Efficiency – 88.2%

CONCLUSION

(a) The development of the low head turbine technology has been undertaken to overcome the present limitations for low head applications with an aim to have a positive impact on small hydro power development. The following challenges need to be addressed for quick adaptation of this technology;

- Technology Approval by recognised agencies
- Policy Support - The implementation of SHP projects is governed by the State policies and the potential sites are allotted by the State Governments to private developers
- Clearance/Approvals: The process of allotment of sites by the States and statutory clearances including land acquisition, forest clearance, irrigation clearance etc. takes long time. Delays in acquiring land and obtaining statutory clearances
• Very few countries have sector specific policy, regulations and notified tariff orders for SHP
• There is a need to treat every project differently as the hydrology and geology of each site varies hence resulting in different capital cost and level of output for the same installed capacity

(b) This turbine technology would overcome the present limitations for low head sites and provide the following advantages:

• A commercially viable turbine which works at low heads i.e. <= 3 m, generally available at the falls in canal systems
• A turbine with a simple design, essentially with very few components out of which only one is moving
• The generator is integrated with the turbine and both are housed within a pipe
• The turbine can be installed using a pipeline and does not require a weir or a dam or a large power house, resulting in lesser requirement for land and substantially lower impact on the environment
• Smaller capacities and remote operation would facilitate electrification in rural and remote areas
• The hydropower plant can be commissioned in less than a year, thereby facilitating early power generation and revenues at a reduced cost
• Turbines using special coatings on steel and also using composites for longer life and MTBM (mean time between maintenance)
• The hydropower plant could be remotely operated and requires no one to be continuously present at site
• Potential to address the Micro & Mini Hydropower segments with a viable and sustainable technology
• Due to the versatility of these turbines, it is possible to address the entire Micro and Mini hydropower segments in a viable and sustainable manner. Series and parallel configurations of multiple turbines, permits enhanced capacity hydropower plants to be set up quickly. Various installation methodologies such as siphons, arrays or the conventional diversion weirs would permit the harnessing of power from canals, rivers or mountain streams. This technology would also find use in water & oil transportation systems and effluent treatment plants. This technology has the capability to address a large portion of the 20,000MW of SHP potential that MNRE is seeking to harness.

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