Standard approach to turbine R&D

A US firm looking at a shaft-based system as a new approach to pumped storage has modified the concept and is also designing small, standardised pump-turbines for mass production. Report by Patrick Reynolds

A RESEARCH project to produce small, standardised pump-turbines rather than larger, site-specific unique designs for hydropower schemes is being undertaken as an in-house, spin-off project by Gravity Power, LLC, the venture-backed US firm focused mainly on developing a modular, deep shaft technology for the energy storage market.

Design development of the smaller-than-typical pump-turbine concept is nearing completion and preparations are being made to have a scale model produced and tested by the Laboratory for Hydraulic Machines, Ecole Polytechnique Federale de Lausanne (EPFL), in Switzerland.

Gravity Power, LLC, says that the standardised production of the pump-turbines would support the modular approach of its core technology: the deep shaft, piston-like acting Gravity Power Module (GPM) system. Typically, clusters of GPM units would be constructed, each unit with its own pump-turbine.

Beyond their use in GPM systems though, the company believes there could be opportunities elsewhere in the pumped storage market for such small, standardised units.

Following the tests by EPFL, the model pump-turbine will be transported to the US and installed for the trials as part of an insitu, scaled GPM unit to be constructed near its offices in Santa Barbara, California. The company is seeking a patent for the GPM system, variations of which could be on land or sea, it envisages.

As the young company continues its R&D effort and financing rounds, it is receiving a lot of interest in the potential of the GPM system from China, India and South Africa, says Executive Vice President, Chris Grieco. Gravity Power, LLC, was launched a year ago as a spin-out business from LaunchPoint Technologies, Inc, a US venture engineering and hi-tech incubator company.

GPM concept – revised

The concept of the land-based GPM system is to have a pair of underground vertical shafts – a main shaft and a narrower, return flow shaft – that form a water-flow circuit. In the sealed system, a concrete mass – the 'piston' – drifts down under gravity to push out water from the main storage shaft and up the return shaft to the pump-turbine, which is mounted at the ground surface, to generate electricity. The flow is discharged back into the main shaft, on top of the 'piston'.

At periods of cheaper electricity on the market, the cyclical GPM system would see the unit work in reverse mode, pumping water back down, injecting it below the concrete mass and so raising the 'piston' to a desired elevation. The GPM system would then be primed with potential energy, awaiting the next call to generate.

Initially, the GPM concept was envisaged as only a single excavated shaft that would hold both the main storage tube (with stored water and the concrete 'piston'), and at least one return pipe. The modular concept would see clusters of such single shafts sunk to deliver the required power capacity, and the storage volumes, that would be sought by different markets and client (see IWP&DC March 2010).

However, earlier this year the concept layout of the GPM system was modified – the single shaft system was completely replaced with an arrangement based instead on a pair of excavated shafts, one large and the other small, for the storage and return flow functions, respectively.

For commercial operations, the size of the largest shaft (storage) – up to 6m diameter or up to 10m diameter – is dependant on project purpose. Neither these nor their depths were changed by the revisions.

For ancillary services to an electricity market, such as grid support and power provision, the shaft would be up to 6m diameter and the return shaft 2m wide. The shafts would be 500m deep.

Much larger shafts and depths are envisaged for the 'peaking plant' GPMs, which would supply steady energy for relatively longer periods and a cluster could have total installed capacities of easily more than 1GW. A GPM unit in such a cluster would have a main shaft of 10m diameter, a 3m wide return pipe and depths of 1km-2km are envisaged.

Pump-turbine research & development

The R&D effort for the new pump-turbines is focused solely at this stage on mathematical modelling with computational fluid dynamics (CFD) analyses, and the in-house research team is led by the company's chief scientist, Dr Jingchun Wu. In the near future the design will be tested in an external hydraulic laboratory and then take part in field trials run by the company.

Dr Wu formerly managed Hitachi's team on turbines and pump-turbines, and worked on hydropower plants designed by Yangtze Water Conservancy Committee, China. More recently, he undertook pump design work for LaunchPoint Technologies, and the work is unrelated to the R&D efforts at Gravity Power, LLC, or the GPM concept.

As part of the research into the small, standardised pump-turbine, Gravity Power, LLC has had discussions with leading hydroturbine manufacturers to seek optimal production solutions, and explore potential collaboration, the company says. But details have not been disclosed.

While the pump-turbine is not integral to the GPM concept it is a strategic complementary offering in the company's package. Therefore, as GPM systems would operate at constant head either pump or turbine mode, the company says the pump-turbine units can be designed to run at its sweet spot for best combinations of efficiency, cavitation risk, etc.

With patents sought for the GPM concept, and being explored separately for the advanced shaft boring technology, it is not however anticipated that the pump-turbine R&D will necessarily result in bonus intellectual property (IP) for the company. The main differential from a commercial perspective, therefore, is volume sales: the company says no-one has had an approach to pump-turbines involving design and production of different standard units to sell not merely as a few or a dozen but in the hundreds, or more.

The key, therefore, is marrying CFD into a series of manufacturing-style standardised designs for a selection of pump-turbines. The CFD-based design is almost done, the company says, and EPFL will soon receive the data to build and then test the model. As further R&D is undertaken, the company says that experience of the industrial pump sector will also be drawn upon to help look at high-volume flows for the pump-turbine systems.

Following the hydraulic tests by EPFL, the model will be among the key components of the GPM installed in Santa Barbara to examine their operational performance. The insitu trial will see the shafts excavated by auger to about 60m depth, which is the limit of the available conventional drill. The installed power capacity of the scaled GPM is to be less than 100kW.

The company anticipates that it will take about 18 months, once it gets underway with the hydraulic model tests in Switzerland and site preparation in California, to finish the design, insitu installation and scaled GPM trails. IWP& DC