Refurbishment of the Pant yr Afon Hydro Scheme

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Abstract

Pant yr Afon was one of the first hydroelectric stations in North Wales, originally commissioned in 1904 to power the slate quarries of Llechwedd for JW Greaves and Sons Ltd and operated successfully for nearly 100 years. Dulas Ltd were contracted to undertake a feasibility study to assess refurbishment options and then complete the turnkey design and reconstruction of this historic scheme. Most of the original equipment and structures had deteriorated too far to enable cost effective refurbishment, hence the majority of the rebuild consisted of new components. The scope of works included refurbishment of the leat system and powerhouse and installation of new intake structures, pipeline, turbine, generator, control system and HV substation.

The project presented some onerous challenges, mostly associated with the difficulties of working on a slate tip, with existing old structures and within a working quarry. Parts of the pipe route were laid over very steeply inclined slate tips at the limit of their stability, with little or no access for machinery. Earthing of the new HV substation proved very time consuming and expensive due to very high ground resistivity and limited areas available to install a suitable earth system, and by complications with interfacing into the existing earth system operated by the DNO.

These challenges were successfully overcome, with the new scheme expected to generate an average of 1700 MWh per year. This provides significant additional revenue for the quarry and an annual saving of 730 tonnes of CO_2 emissions. Furthermore, the display of old and new technology within the same building provides a historically valuable site, effectively illustrating the development of hydro turbines, generators and control systems over the last hundred years.

History

The Pant yr Afon hydro scheme was originally commissioned in 1904 to provide power for the Llechwedd Slate Quarry operations. Two Gilkes Pelton turbines, each rated at 270 kW, were installed to drive open frame 500V DC generators. The original DC system was controlled by hydraulic governors to match the generated power to the quarry load demand. In later years, the system was grid connected via a rotary converter to export surplus electricity to the grid. The system operated successfully for almost 100 years until damage to the generators during heavy storms eventually brought the turbines to a standstill in 2003.

A detailed feasibility study, commissioned by the quarry owners JW Greaves and Sons Ltd and carried out by Dulas in 2003, concluded that much of the original system was in such poor condition that it would be unsuitable for refurbishment. Over the following years a detailed plan was developed to build a new grid connected scheme at the site. In partnership with the quarry managers, this involved negotiating planning permission and new abstraction licences and identifying the technical scope of works required. In 2006, Dulas Ltd were successful in tendering for the turnkey design and construction of the new scheme in a 12-month contract, valued at £700,000.

Scheme Outline

There were originally two separate hydro schemes operational at the site; a smaller scheme constructed in 1927 is located higher up in the catchment at the Maenofferen quarry. The discharge from the Maenofferen turbine enters a leat that leads to the start of the pipeline that feeds the Pant yr Afon turbines. Hence, the two schemes are inextricably linked, as the control of water within the Maenofferen system is essential to maximise the use of water resource and generation at the Pant yr Afon powerhouse. The feasibility study needed to assess how to control the various water resources and how to optimise generation from the two schemes. The obvious solution was to refurbish and then operate both schemes in tandem with a combined control system.

Detailed computer models were designed to establish the optimum scheme sizes and operating conditions to make best use of the water resources. The model was complicated due to the combination of three reservoirs and an additional large catchment area that contributed a significant, but relatively uncontrollable water resource. Due to the higher head of the Pant yr Afon scheme, and the larger combined catchment area, this scheme generates the majority of the energy, with the Maenofferen scheme being controlled in a slave state, running at flows designed to maximise water resource for the lower Pant yr Afon scheme. The model showed that the Pant yr Afon scheme would have a maximum capacity of 400 kW, with the Maenofferen scheme requiring a maximum capacity of around 150 kW for peak flows but would operate for much of the time at around 70-100 kW.

The refurbishment of the schemes was split into two projects but with the intention of both schemes being refurbished concurrently. Dulas were successful in winning the tenders for both projects, however, due to problems with administration of one of the grant schemes, the Maenofferen project has still not commenced. This paper therefore deals with the development of the lower Pant yr Afon scheme.

Scope of Work

The feasibility study showed that a new 400 kW, single jet Turgo turbine was the most appropriate turbine choice. The refurbishment of the scheme included the following works:

- Installing an automated flow control valve and level sensor at Llynnau Barlwyd to allow remote control and optimisation of the water storage. (Following subsequent inspections of this old reservoir, there are some doubts over the allowable storage capacity and this work is on hold at present).
- Refurbishment of the 1200m long leat between Llynnau Barlwyd and the pipeline header pond, including construction of 4 new intakes to provide screening and regulation of the abstracted water into the leat from the streams crossing the leat route.
- Construction of a new screened pipeline intake chamber.
- Removal of the old 450mm diameter steel pipeline and replacement with 1130m of new fusion welded polyethylene pipeline, with a new manifold to supply both new and old turbines.
- Extensive modifications to the existing powerhouse building to allow construction of the new turbine and generator foundations and new tailrace channel to connect to the existing turbine tailrace.
- Installation of Gilkes Turgo turbine, Amco Marelli 600V synchronous generator, Dulas automatic control system with touch-screen HMI and SCADA.
- Installation of 200m of 600V, 4-core, 300mm^2 twin power transmission cables to 400V/11kV transformer and HV switchgear.
- Construction of a new substation to contain transformer and switchgear to allow grid connection to the nearby 11 kV overhead lines.

Design and Construction Challenges

Pipeline

The lowest 200m section of pipeline runs over the surface of a steeply inclined slate tip before passing under the A470 trunk road and entering the powerhouse at a pressure of 16 bar. With a slope of up to 37 degrees, the tip is considered at its limit of stability; the challenge was to remove the old steel pipeline and safely install a new pipeline without danger of disturbing the tip or threatening the A470.

Since working on the tip face with machinery was impossible, this eliminated most conventional methods of pipeline construction or materials. After discussions with the quarry’s Geotechnical consultant, the preferred solution was to install a butt fusion welded polyethylene pipeline that could be welded above the tip in a safe location and progressively lowered down the tip face. Specially designed sledges and rollers were used to allow removal of the old pipeline and installation of the new pipeline while minimising disturbance to the loose slate waste. A second hand conveyor belt was installed on the ground surface down this section of tip, prior to laying the new polyethylene pipe, to avoid damage and potential compromise to the integrity of the pipe. Using these methods, this section of pipe was safely replaced without any significant disturbance to the slate tip.

Since virtually all the pipeline between intake and powerhouse is above ground, the use of butt-welded pipe eliminated the need for numerous restraints and anchor blocks apart from one at the top of the tip and one at the entrance to the powerhouse. This was a significant advantage given that most of the ground material was of made up slate waste with unpredictable characteristics.

A disadvantage of surface installed polyethylene pipe is its high coefficient of expansion. The change in length of pipe between a cold night and a warm sunny day was considerable and presented significant problems in joining this pipe to the buried section that enters the powerhouse.

Powerhouse

Although fusion welded pipe does not generally require anchor blocks, it is essential that the manifold entering the powerhouse is absolutely immovable, to prevent any transmission of hydraulic forces onto the turbine. For this reason, and for additional security, a large (approximately 25m^3) concrete anchor block was poured outside the powerhouse. The anchor block was very close to the old dry stone abutments supporting the A470, with the potential to destabilise the foundations during excavations. During construction, the anchor block hole had to be deepened further than expected in order to find solid ground and avoid potential settlement. To minimise risk of collapse, the anchor block was poured in sections. The pipe route through the tunnel under the A470 also had to be rerouted slightly to avoid disturbance to the tunnel foundations.

Substantial excavations were required within the powerhouse to allow the construction of the reinforced concrete foundations for the turbine and generator and new tailrace channel. Great care had to be taken to avoid disturbance to the existing wall and turbine foundations, which were all constructed from large slabs of dressed slate.

The new turbine, generator and control system was installed adjacent to the old turbines and it was particularly satisfying to install a third Gilkes turbine next to the original Gilkes machines that had been in the powerhouse for over 100 years. It is interesting to note the new turbine and generator are less than half the size of each of the original machines while producing 50% more power. The new manifold to the powerhouse still supplies the existing turbines to enable them to be turned at low speeds; it is intended that the powerhouse will form part of the quarry visitor centre tour.

Grid Connection

Unexpectedly, this became the biggest obstacle to completing the scheme. As part of the work carried out by the DNO to enable the grid connection, it was discovered that the HV earth for their nearby existing substation that supplied part of the quarry had degenerated over time and was unsafe to operate. The quarry was immediately disconnected by the DNO and supplied by a LV diesel generator, while a new earth was installed. Due to the very poor ground conditions (compacted slate waste with very high resistivity), the DNO found it necessary to install around 600m of earth, which took them over 6 months to complete.

Dulas were responsible for the hydro substation HV and LV earths. Unfortunately for the hydro scheme, the most effective solution was to combine the new hydro and existing substation earths. It was therefore necessary to wait until the DNO had completed their earth and negotiate a connection from the hydro substation to this system, at what turned out to be a very high cost and with significant delays to the project.

Summary

The installation work was completed on schedule at the end of May, however at the time of writing the grid connection had not been completed and the scheme is still awaiting commissioning. It is hoped that the plant should be fully operational by early October.

The key lessons from this experience are to undertake detailed soil resistivity tests at an early stage in the project, and in all cases to ensure that delays caused by third parties do not become a liability for the scheme as a whole.