Hydro Schemes: Descriptions

This document relates to the Scottish Hydro collection of photographic images held at RCAHMS, Edinburgh.

Compiled by Mr George Walker 2005.

Introduction

The North of Scotland Hydro-Electric Board was set up in 1943 largely due to the energy and commitment of Tom Johnston, Secretary of State for Scotland, in convincing the skeptics of developing the Highlands and utilising a natural source. Prior to 1943 there existed several small hydro schemes, mainly developed by the British Aluminium Company at Fort William and Kinlochleven, and by the Grampian Electricity Supply Company in the Tummel-Garry area. The latter development took place between 1928 and 1940, during which year 106 million kilowatt hours was supplied to the Central Electricity Board.

The Hydro Board had several very capable engineers such as A.E.MacColl, Angus Fulton, W.Guthrie and David Fenton, whose drive and commitment were to prove vital later on.

The constructional schemes for Loch Sloy and Tummel-Garry met with severe opposition, but the continueing increase in demand for electricity won approval in the end. The main problem is peak demand, to which thermal plant cannot rapidly respond. However hydro plant can be started and stopped in a matter of minutes. Thermal plant can therefore handle the base-load, while hydro plant can rapidly respond to fluctuations in demand.

Types of Scheme

Various types of construction are necessary due to the local topography, rainfall and run-off. One of the problems facing the engineers is the scarcity of hydrographic data for remote areas, and this has to be determined at the planning stage.

The various types of scheme are as follows :

1. **Without water storage**

2. Dam to provide storage and head
3. Using mountains or steep hills to develop heads many times greater than the highest dam
4. Pumped storage

1. The run-of-river schemes rely on very high flow rates since there is a minimum of head. Usually a weir is constructed across the river at a narrow part and includes a turbine in the weir.
2. This type incorporates a dam to provide storage and a moderate increase of head, and also relies on large flow. The turbines are built into the dam.
3. A high level loch feeds water into a pipeline on a steep slope, supplying a power station beside a low level loch. This type of system relies on a large head.
4. The pumped storage scheme uses excess power during periods of low demand to pump water from a large low-level loch to a high-level one.The stored water is used during peak demands to generate at a power station beside the lower loch.

The type of turbine is also dependent on the available head. If this is low a Kaplan or propeller turbine would be used. For a high head a Pelton or a Francis turbine is more suitable.

The Loch Sloy Scheme

This was the first scheme to be tackled in 1945. Serious problems soon arose due to the post-war shortages of manpower and materials. The first of these was addressed by employing several hundred German prisoners-of-war. Access problems required the building of roads and conveyors for materials landed from Loch Lomond. Severe weather conditions delayed progress and completion of the project took place in 1950.

A dam of massive buttress type was built at the south-eastern end of Loch Sloy leading to a tunnel through Ben Vorlich, followed by four circular pipelines leading to the power station at the side of Loch Lomond. A surge shaft was incorporated in Ben Vorlich.

The generating sets consist of four vertical shaft Francis turbines each coupled to a 32,500 kW alternator. Delays were again occurring due to

adverse weather and transport problems for the heavy equipment, which was finally installed by 1950. When fully loaded the turbines pass a million gallons of water per minute.

The Tummel-Garry Scheme

The second of the Hydro Board's schemes was an extension of the Grampian Electricity Supply Company's scheme. The Clunie dam was constructed at the east end of Loch Tummel, increasing its size. A tunnel connects to Clunie power station below the Falls of Tummel. A dam was built at the east end of Loch Errochty whose water was fed by a tunnel and pipeline to a power station at the head of Loch Tummel. Finally the River Tummel was impounded at Pitlochry forming Loch Faskally. The power station here is built into the dam and incorporates a fish ladder to allow salmon to pass. Loch Faskally forms a balancing reservoir for fluctuations in flow due to the Clunie power station's operations.

The scheme produces a total of 150,000 kW. Work started in 1946 and experienced similar problems to Loch Sloy due to shortages of labour and materials, being completed in 1951.

The Conon Scheme

This project involves three separate stages : the Fannich scheme, the Glascarnoch-Luichart-Torr Achilty scheme and the Orrin scheme.

The first of these involved tunnels and aqueducts to increase the flow into Loch Fannich, and a tunnel from the bed of Loch Fannich to the Grudie Bridge power station at the west end of Loch Luichart. This involved a severe problem at the Loch Fannich end. Work began in 1946 and a dam was built later, completing the section in 1951.

Work began on the second stage in 1951, producing two artificial lochs Vaich and Glascarnoch by damming the respective rivers, using the earth and rockfill method. Tunnels were excavated between these lochs and from Loch Glascarnoch to Mossford power station on Loch Luichart. A dam at the east end of Loch Achanalt allows this loch to supply the Achanalt power station near Grudie Bridge. Two attificial lochs Meig and Achonachie were produced by dams on the rivers Meig

and Conon to supply power stations at Luichart and Torr Achilty respectively. Work on this section was completed in 1957.

TheOrrin scheme was started in 1955 and involved the construction of a mass gravity dam 1000 feet long and an earth embankment also 1000 feet long to seal off a branch valley, thus forming the Orrin Reservoir. The outflow is through a concrete-lined tunnel to a steel pipeline supplying the Orrin power station on Loch Achonachie. Four Borland fish lifts were installed to accommodate water level variations in the reservoir. This type of fish lift had been installed at Luichart, Meig, Achanalt and Torr Achilty. The scheme was completed in 1961, the six power stations producing an output well over 100,000 kW.

The Affric-Beauly Scheme.

Work was begun on the construction of the Mullardoch dam in 1947. This is of the mass gravity type and is 2385 feet long by 160 feet high, impounding 7.5 million cubic feet of water. A tunnel was excavated from Loch Mullardoch to Loch Benevean, and another from the latter loch to Fasnakyle, the main power station on the River Affric, both tunnels being over three miles long. The Fasnakyle tunnel splits into three steel-lined tunnels near the power station, each supplying a 22,000 kW vertical Francis turbo-alternator.

The second stage of the scheme involves the rivers Farrar and Beauly. Water is impounded in Loch Monar by the Monar Dam, supplying the Deanie power station at the west end of Loch Bennacharan which is dammed at the east end to feed Culligran power station, whose outflow into the River Farrar then flows into the River Glass. These power stations generate 38 MW and 24 MW respectively. The River Glass flows into the River Beauly which has dams and power stations at Aigas and Kilmorack, each a 20 MW run-of-river station. These dams are provided with flood control, Borland fish passes and compensation water facilities with or without generation. The scheme was completed in 1963.

The Great Glen : Garry/Moriston Scheme

The Garry part of the scheme uses the stotage facility of Loch Quoich to supply Quoich power station via a tunnel from the dam, which is the

largest rockfill type. Two further dams were required at the west end of the loch. The outflow goes via the River Garry to Loch Garry, and eventually via a tunnel to Invergarry power station at Loch Oich. There is a dam at the east end of Loch Garry. A fish stopper and trap were built down-stream of Quoich power station.

Storage for the Moriston section was provided by damming Loch Loyne and Loch Cluanie, and interconnecting them by a tunnel. A second tunnel from Loch Cluanie supplies Ceannacroc power station which discharges into the River Moriston, which in turn feeds Loch Dundreggan.This loch is also fed by the outflow of Livishie power station, supplied by a system of aqueducts. Glenmoriston power station is just below the Dundreggan dam. Its outflow reaches the River Moriston at Loch Ness via a tunnel. These three power stations were built underground for environmental reasons. The control centre for the entire scheme is at Fort Augustus. The total output capacity is 114 MW. The scheme was built between 1949 and 1962.

The Shin Scheme.

Work began 1954 on the Lairg dam, a concrete gravity and earthfill type, at the east end of Loch Shin. Lairg power station was built into the dam and employs a vertical Kaplan turbine generating 3.5 MW. Outflow is into Little Loch Shin which supplies Shin power station through a tunnel. This station has two horizontal Francis turbines generating a total of 24 MW. Cassley power station at the west end of Loch Shin is fed by aqueducts and a tunnel, and produces an output of 10 MW. A Borland fish lift was provided at Lairg dam. The scheme was completed in 1960.

The Breadalbane Scheme.

Construction took place between 1951 and 1961 in two sections north and south of Loch Tay respectively. Dams were built at the east ends of Loch an Daimh, Loch Lyon, Loch na Lairige and Stronuich Reservoir, supplying Cashlie, Lubreoch, Finlarig and Lochay power stations respectively in the northern section. Water collection is by a considerable group of aqueducts and tunnels in the areas of the River Lyon and the River Lochay and their tributaries. Finlarig power station is noted for operation at a head of 1348 feet, the highest of any of the

schemes, and produces 30 MW from a Pelton turbine-driven alternator, the largest of this type in Britain.

The southern section has dams on Loch Breaclaich and Loch Lednock, these lochs being interconnected by a tunnel, with a power station at the entry to Loch Lednock. The latter discharges via a tunnel to St. Fillans power station at the east end of Loch Earn, which in turn supplies Dalchonzie power station, which outflows into the River Earn. Aqueducts and further tunnels collect water from the surrounding area. The total output from the scheme is 120 MW.

The Shira Scheme.

Dams were built at Lochan Shira, Lochan Sron Mor and the reservoir supplying Allt na Lairige power station via a tunnel. Sronmor power station is fed by an aqueduct from Lochan Shira. Aqueducts and a long tunnel supply Clachan underground power station at the top of Loch Fyne at a head of 965 feet. Sronmor was supplied with pumping facilities in effect to give Clachan the advantage of pumped storage. The installed capacity of the scheme is 51 MW. Construction took place between 1951 and 1959.

The Loch Awe Scheme.

The Loch Awe Scheme took place in the 1959-1967 period and comprised three power stations Inverawe, Nant and Cruachan, the latter two being underground. Inverawe is supplied by a tunnel from Loch Awe and discharges into Loch Etive, whereas Nant is fed from Loch Nant by a tunnel supplemented by an aqueduct collecting from local streams, and discharges into Loch Awe. These stations have installed capacity of 25 MW and 15 MW respectively.

By far the largest power station is Cruachan at 400 MW, and is a pumped storage system, making use of Cruachan Reservoir at an altitude of 1316 feet to give a head of 1198 feet. During off-peak periods at night and week-end water is pumped up to the reservoir from Loch Awe using available excess power. The water is used to generate during daytime demand, discharging into Loch Awe.

The project involved the design and development of special turbines that could be utilized as pumps against a high head, and alternators that could be driven as motors. A buttress dam was built at the exit end of Cruachan Reservoir, and several tunnels to collect water from the surrounding area. Problems at the lower level were largely caused by conjestion at the Pass of Brander, leading to the decision to build the power station in the heart of Ben Cruachan. This involved an enormous amount of excavation, made difficult by geological problems. Later on problems arose due to the necessity to assemble large machinery in confined space under controlled conditions. Also difficulties were encountered with the outfall into Loch Awe. However in spite of the difficulties the project was successfully completed to specification in 1967.

The Foyers Scheme.

Like the Loch Awe scheme the Foyers one is a pumped storage system. It was a redevelopment of the previous scheme built by the British Aluminium Company whose smelter ceased operation in 1967. The upper reservoir, Loch Mhor, had two dams built at its west end, and is fed by an aqueduct from the River Fechlin draining Loch Killin. A tunnel connects Loch Mhor and the Foyers power station on the shore of Loch Ness. Nearby is a second power station Foyers Falls.

The main construction problem was due to the Great Glen Fault shatter zone, causing routing and tunneling difficulties. Foyers power station has two reversible turbines capable of lifting 160 tons of water per second to Loch Mhor, and outputs 200 tons per second to Loch Ness when generating a full load of 300 MW. The scheme was begun in 1969 and completed in 1975.

Reference.

Further details of the above schemes and the history of the North of Scotland Hydro-Electric Board may be obtained from the following book :
"The Hydro" by Peter L Payne, Aberdeen University Press, 1988.
RCAHMS Library reference J5.14 PAY.

Definitions of Terms Used.

Alternator : generator of alternating voltage and current (AC)
Amp : unit of electric current (contraction for Ampere) (A)
Dam : barrage to impound water in a loch, and consists of several types e.g. mass gravity, arch or buttress
Draft Tube : the water outlet from a turbine
Head : vertical distance from storage loch to power station in feet
Kilovolts : electrical pressure of generated supply in thousands of volts (kV)
Megawatts : rate of power output generated in millions of watts, equal to kilovolts X kiloamps, (MW)
Pipeline : steel pipes carrying water from storage loch down to power Station
Power station : building containing turbines, alternators, transformers, monitoring and control gear, may be built on the surface, into a dam or underground
Pumped storage : a system of generation in which the alternator and turbine can act as motor and pump to lift water from a lower to a higher reservoir, using off-peak electric power during night-time and weekend, and generating normally during high daytime demand e.g. Cruachan (Loch Awe) and Foyers (Loch Ness) schemes
Rotor : the revolving part of an alternator
Spillway : bypass for a dam to remove excess water during flood Conditions
Stator : the stationary part of an alternator
Surge chamber/shaft : space at the bottom of a pipeline to absorb shock by allowing water to flow in and out, avoiding destructive "water hammer"
Tailrace : conduit returning outflow water to downstream side of river or to lower loch
Three phase : alternating voltage or current waveforms as sine-waves differing in phase by 120 degrees, on three separate conductors, the phase rotation order being determined by red, yellow and blue colour coding
Transformer : a static device for increasing or decreasing voltage of a supply, the corresponding current being decreased or increased respectively, thus keeping the power in watts constant

Transmission lines : distribution of electric power by conductors suspended from and insulated from steel pylons carrying one or more three-phase supplies at 132 kV or 275 kV, the latter being termed the national supergrid, voltage being reduced by transformer for local transmission in steps to 33 kV, 11 kV and for domestic supply to 240 V

Turbine : a rotary power machine operated by water power, and may be of two types, high pressure where a high head is available, or high flow on a large river, e.g. Loch Sloy and Pitlochry schemes respectively

Vanes : the metal blades on the stator and rotor of a turbine which cause rotation by the input water jets

Cofferdam : an enclosure made in a river or loch by driving steel piling into the base and pumping out the impounded water, thus allowing work, e.g. concreting, to proceed.

conditions

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List of Lochs in each of the Schemes.

The Loch Sloy Scheme
- Loch Sloy
- Loch Lomond

The Tummel-Garry Scheme
- Loch Cuaich
- Loch Eigheach
- Loch Ericht
- Loch Errochty
- Loch Fascally
- Loch Garry
- Loch Rannoch
- Loch an-t-Seilich
- Loch Tummel

The Conon Scheme
- Loch Achanalt
- Loch Achonachie
- Loch Droma
- Loch Fannich

Loch Glascarnoch
Loch Luichart
Loch Meig
Orrin Reservoir
Loch Vaich

The Affric-Beauly Scheme
Loch Affric
Loch Beannacharan
Loch Benevean
Loch Monar
Loch Mullardoch

The Great Glen : Garry-Moriston Scheme.
Loch Cluanie
Loch Dundreggan
Loch Garry
Loch Loyne
Loch Ness
Loch Oich
Loch Quoich

The Shin Scheme
Loch Flag
Loch a'Ghriama
Loch Merkland
Loch Shin
Little Loch Shin

The Breadalbane Scheme

Loch Breaclaich
Loch an Daimh
Loch Earn
Lochan na Lairige
Loch Lednock
Loch Lyon
Stronuich Reservoir
Loch Tay

The Shira Scheme
Allt na Lairige Reservoir
Loch Fyne
Loch Shira
Lochan Sron Mor

The Loch Awe Scheme
Loch Avich
Loch Awe
Cruachan Reservoir

Loch Etive
Loch Nant
Loch Tulla

The Foyers Scheme
Loch Killin
Loch Mhor
Loch Ness