You would think generating a bit of electricity from water flow would be straightforward, wouldn't you? Well here is a highly condensed explanation of how it all works.

The electrical generator was invented by Michael Faraday in 1831. His early ideas were first converted into a practical industrial energy source in the 1860s and used to generate heat for steel manufacture. Interestingly, Siemens Bros, were one of the largest UK (and global) producers of electrical generators in the latter part of the 19th century and early part of the 20th century, until the first world war resulted in the business being sequestrated and absorbed by English Electric. One of their generators was used in the first UK hydroelectric generation systems installed by William Armstrong at his high-tech "des res" at Cragside in Northumberland in 1870.

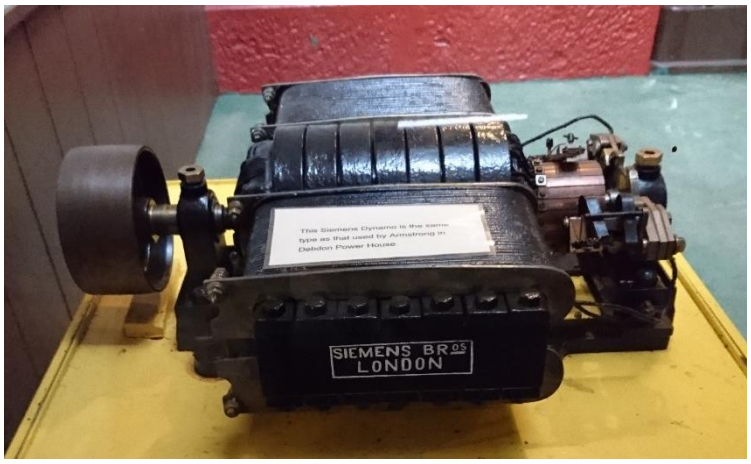
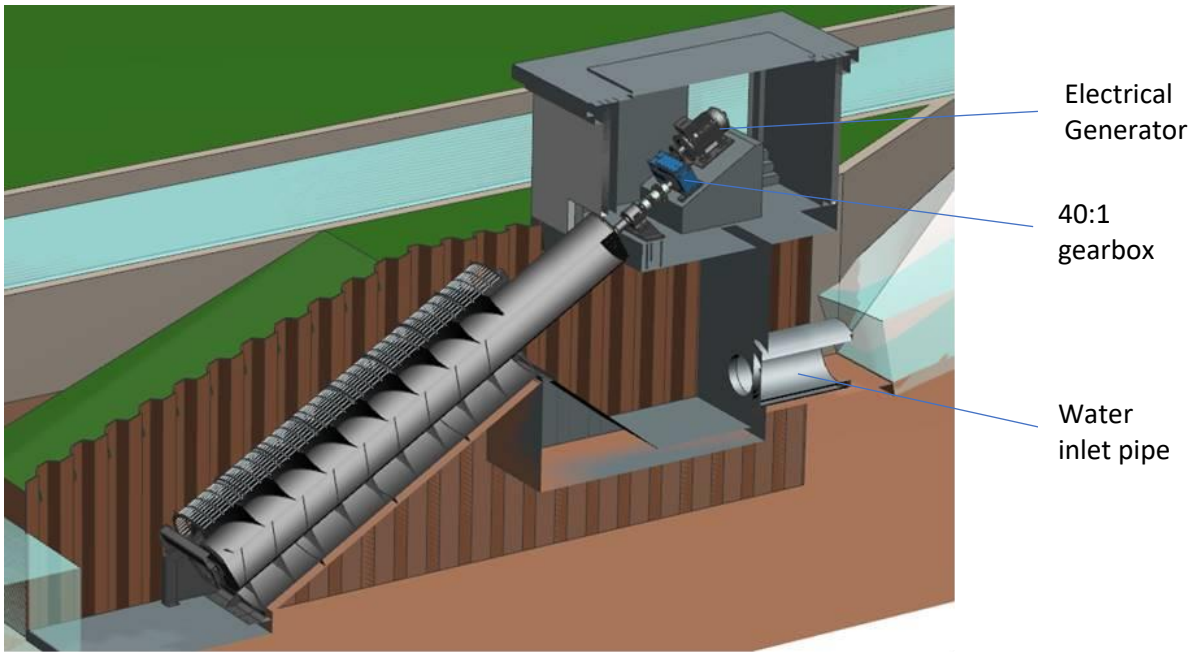


Figure 1: Siemens dynamo installed at Cragside

The original generators produced direct current. However, in the latter part of the 19th century it was realised that efficiently transporting the electricity to a wider network from a large generator was particularly challenging due to the resistive losses in the cables. This resulted in the development of the alternating current (ac) generator which lends itself to easy conversion to high voltages for transmission over long distances, then subsequent conversion back to the lower voltages needed for appliances in factories and homes. The first ac power station and distribution network were installed by Sebastian Ferranti at Deptford in 1887 and our modern electricity network is still based on the same principles used there.

So how do we convert the mechanical energy from the screw into electrical energy to export onto the grid?



As explained in the associated article, the Archimedes screw can only operate efficiently at relatively low rotation speeds (3-30RPM) and electrical generators only work efficiently at higher speeds, so a 40:1 gearbox is used between the shaft of the screw and the shaft of the generator.

To optimise power generation over as wide a range of river flow conditions as possible the speed of rotation has to be variable. As asynchronous generators directly connected to the grid only work efficiently when their rotation speed is close to the so-called "synchronous speed" dictated by the 50Hz mains frequency, a variable speed power electronics converter is needed to allow power generation over a wide range of rotation speeds.

The system uses an electronic inverter with an active front end.

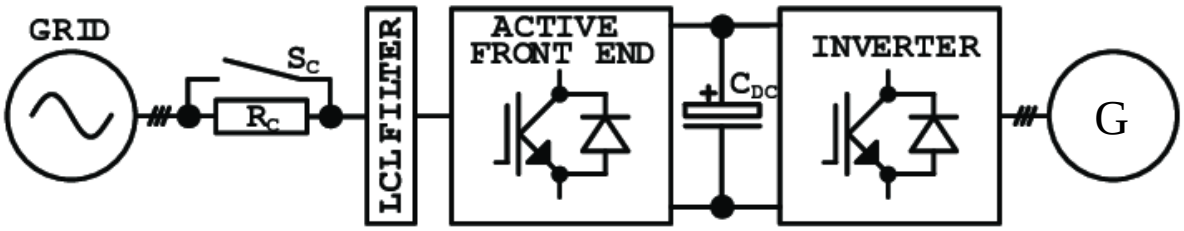


Figure 2 - Variable Speed Drive with Active Front End

The grid voltage is connected to the bi-directional front end of this device which converts it to DC. The DC voltage is then converted electronically to a variable voltage, variable frequency ac voltage, which is applied to the generator. This voltage is used to apply braking torque (via the generator and

gearbox) to the Archimedes screw, the energy from which is fed back into the DC link. The active front end then generates a 50Hz voltage (synchronised to the connected mains supply) with variable amplitude and phase. By adjusting the phase of the voltage produced, the amount of output power to the grid can be controlled. A control loop regulates the DC link voltage by controlling the export power to ensure that all the energy being generated by the screw is exported.

Using a variable speed generator allows the water level at the top of the screw to be controlled to suit the flow rate in the river by slowing down (or speeding up) the generator. This increases the proportion of time in the year during which efficient generation can be achieved.

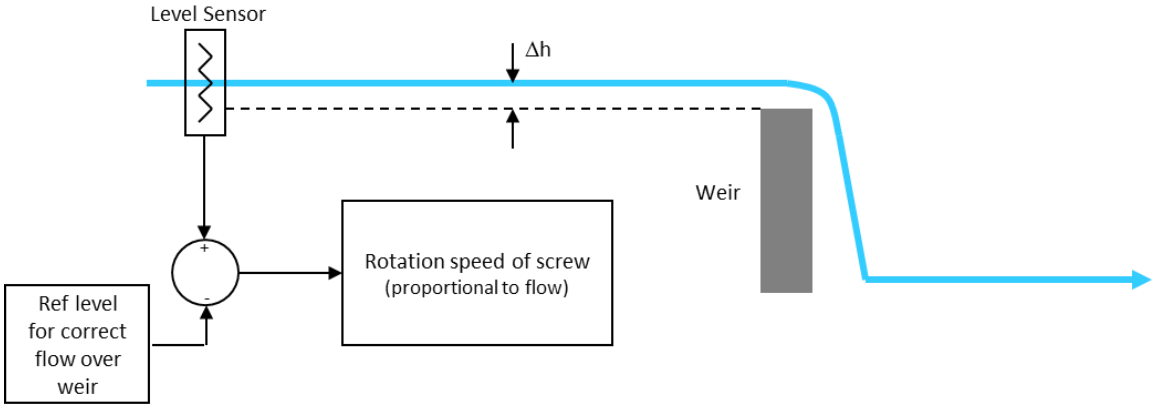


Figure 3: Weir water level control principle

The slow rotation speed of the screw also means that fish can safely swim into the compartments and have a joy ride down to the bottom. Going back up is more of a challenge, but the Environment Agency is currently considering installing a fish-pass, which they can swim up.

Figure 4 The Control Cabinet including Variable Speed Drive and PLC control system