Energy From a Bucket of Water

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Archie Simulator

To mimic the operation of Archie and the weir a simulator has been designed to offer learning opportunities to school students at Key Stage 2 and 3. Briefly the system comprises a 'bucket' containing a known volume of water raised to a fixed height with a valve to control the rate of flow from the container through a small turbine driving a (safe low voltage!) generator together with some simple electronics we're calling 'Little Arch'. The challenge is to operate the valve to maximise the useable electrical energy produced by Little Arch. The feed and turbine are pictured below.

"The Bucket"

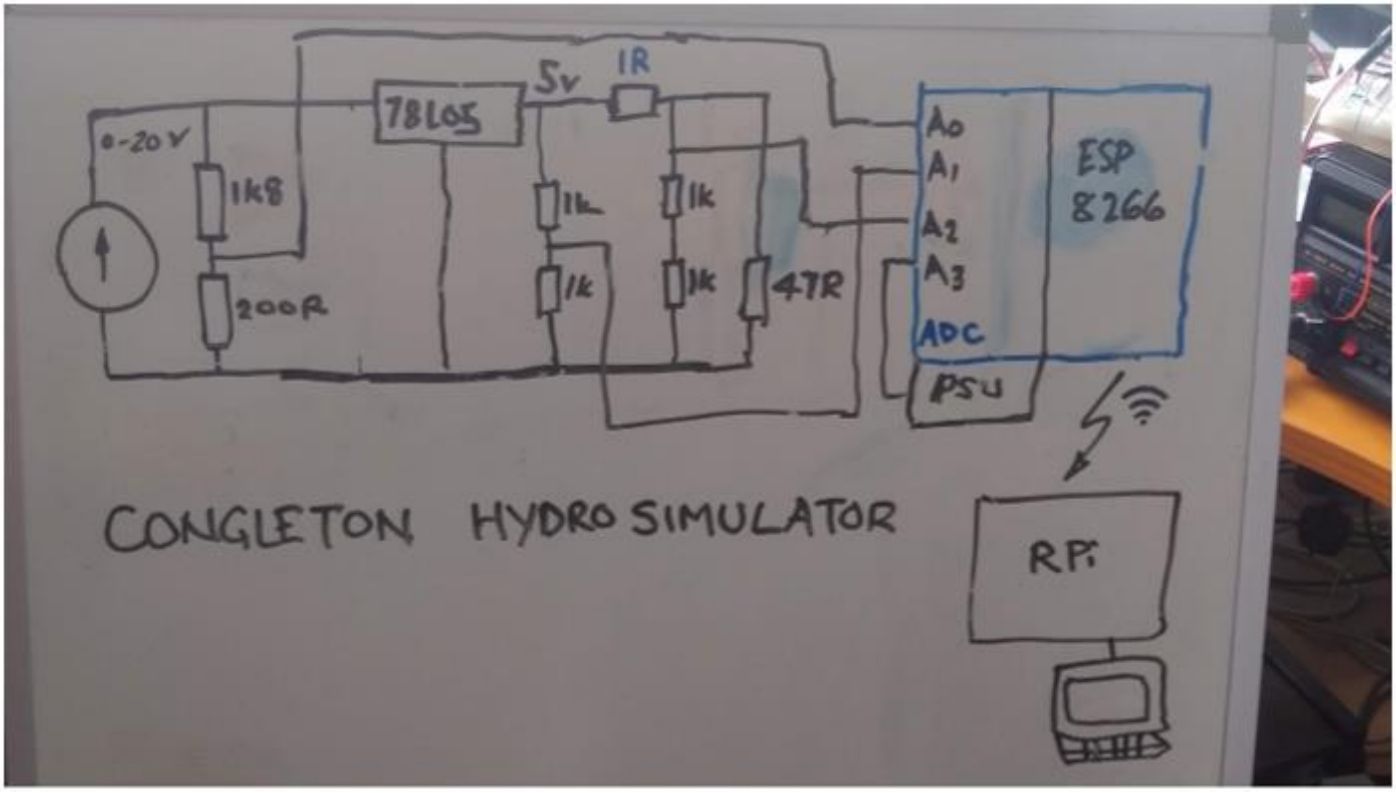
"B&Q Plumbing" and a small turbine generator

Not all the available power provided by the river can be converted to electrical energy by Archie due to losses in the system from friction in the moving parts, such as bearings, the gearbox and the generator. Some energy is also lost to heat in the connecting cabling and generator windings. To be able to use the generated electricity effectively the output needs to be maintained at a fixed voltage. Regulation equipment in the control cabinet looking after Archie makes sure that this is continuously achieved.

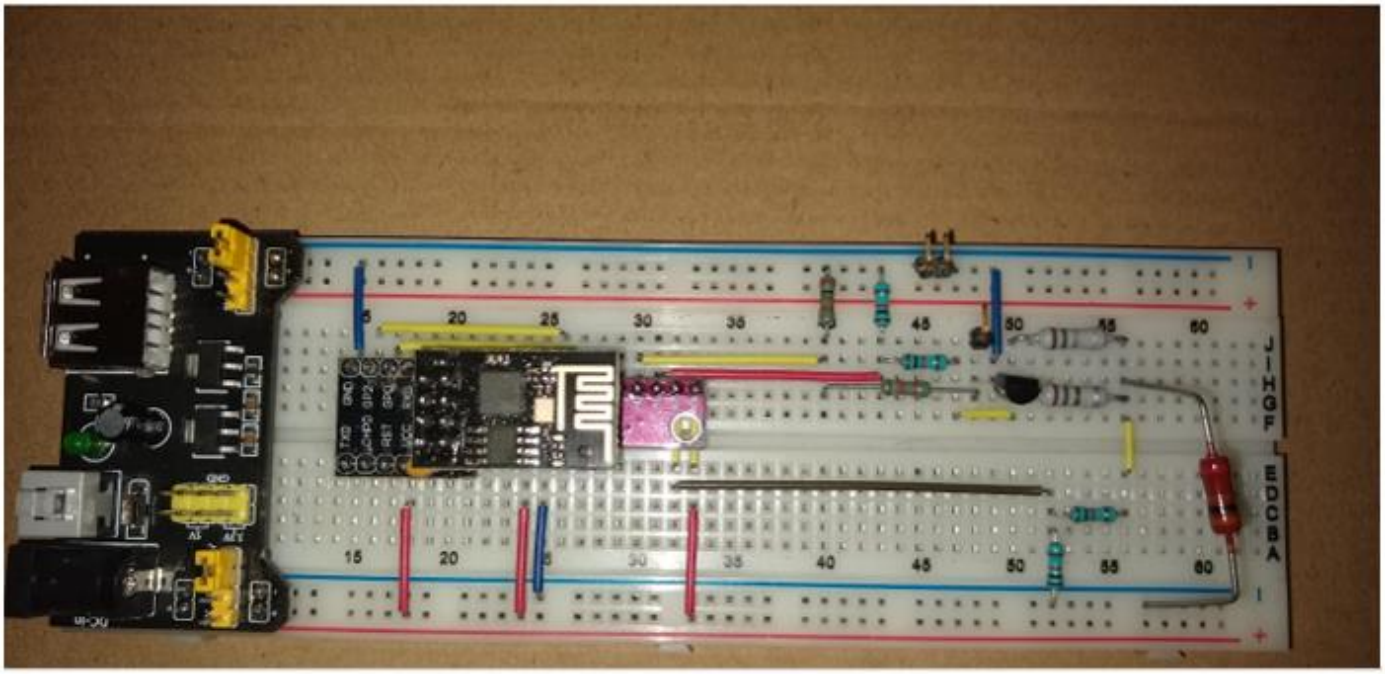
The flow of the Dane varies greatly with the seasons and there can be rapid changes in the water level when the river surges after heavy rain. The screw operates within a range of water levels - too low and there is insufficient rotational energy to provide the required voltage output, too high and Archie could over-speed and cause damage to himself and the connected equipment. This is the core benefit of the use of variable speed drives ie the maintenance of a useable output over a wide range of flow.

Little Arch simulates the behaviour of the real system by using a semiconductor voltage regulator to deliver a constant output voltage. If the input voltage from the generator is too high, due to high water flow, the regulator protects itself from excessive heat dissipation (loss) by reducing the output voltage. If the flow is too low Little Arch will not produce any output at all.

Circuit diagram showing all main components and the interface to an A-D convertor so that real time data can be transmitted to a Raspberry Pi and even mobile phones.



Little Arch constructed on a solderless breadboard with the pink A-D convertor hiding under the wireless transmitter. (The big green thing on the left supplies power to the system).



Little Arch simulates operation of the river, Archie, the control system and associated losses. Careful manipulation of the valve will keep Little Arch's output constant and minimise losses. Of course, as the 'bucket' empties the pressure remaining will reduce so the valve must be carefully adjusted to maintain the output voltage.

This may not be easy as only a fixed volume of water in the bucket is available! A number of ‘runs’ will be needed to get the best possible output.

For KS2 students the amount of energy produced can be indicated by the length of time a string of led’s remain illuminated. For KS3 the energy produced can be measured using meters and a stopwatch or by electronic means giving the possibility of using a small computer such as a Raspberry Pi to collect and display real data using open source software already in use with IOT (Internet of Things).

As with Big Archie, things don’t always work to plan. You will notice for the initial concept testing we managed to acquire a water canister” from an office drinking water system. To simulate the Weir Head, we decided to pressurise this cannister (0.1bar is equal to about 1metre head). This was done by fitting a Schrader valve (same as fitted to car tyres) and pressuring using a Halfords tyre pressure inflator (other brands are available!!!). Now we know how difficult it is to build a ship in a bottle! After much innovation with lengths of string, lengths of bent wire (what would we do without wire coat hangers!!) the Schrader valve was installed. Office water cannister was then duly filled and pumped up and we then find out that office water cannisters are not designed to be pressurised---it is amazing how big a bulge can be produced without it bursting! Anyway, it was good enough for our testing and showed that the “proof of principle” was indeed feasible.

Little Arch has completed initial testing and a current of 95 milliamps at 5 volts has been demonstrated. The next step is to construct a soldered prototype and is hoped to subsequently produce a custom printed circuit board that students can build.

We are anticipating keen competition to see who can become an energy master by consistently beating others for a high score!

Design, construction, test and use of the simulator makes an ideal STEM project that can be undertaken by after school clubs over a few weeks. It could even be possible to arrange a league table allowing schools to compete against each other in a grand championship!

Of course, all this needs to be done within a tight material cost budget and, where possible, using items already available in school. We expect to produce a kit of parts and comprehensive instructions for our school partners so you could even build one yourself at home!

Next stage is to move from a lash up into something that is more robust and using more suitable materials e.g. suitable water container to pressurise etc.

We will try to keep you up to date with progress.