A Microhydro Learning Experience

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with Jo Hamilton and Rose Woofenden

The potential for microhydroelectric power can't be beat the way it rains in the North Cascade mountains of Washington State. The climate in the foothills is wet, and many trees are covered with thick moss. It is cloudy much of the year, and though solar and wind are options, hydro is more cost-effective for those with a good stream. At Floyd and Frasia Omstead's property in the Skagit River valley, hydro is the best renewable solution. Although grid power is close, the Omsteads prefer to have the independence and reliability of a hydroelectric system.

Ian Woofenden (my dad), Solar Energy International's (SEI) Northwest coordinator, approached Floyd with the idea of installing a hydroelectric system as part of an SEI workshop. They had met two years earlier when Floyd attended an SEI PV workshop. After considering the pros and cons, Floyd agreed to provide the installation site for the SEI microhydro workshop.

The workshop was held in October of 1999. A class of students spent five days learning about microhydro. They came from the Northwest and beyond, including Montana, Pennsylvania, and California. There were students planning to work in the renewable energy industry, others who wanted to build their own hydro systems, and one student who had concerns about the Y2K computer bug. There were also those who wanted to learn more about the systems they were already living with.

Hydro Education & Experience

The first two days were dedicated to classroom instruction taught by Bob Mathews from Energy Alternatives of British Columbia, Canada. Bob is very knowledgeable about microhydro, and has designed many systems in Canada and in the U.S. His organized and detailed approach gave the students a real grounding in microhydro theory and design principles.

On the third day of the workshop, we toured a couple of hydro systems, led by SEI instructor Johnny Weiss. First we stopped to see Chris Soler, who has a small homebrew system with a Harris Pelton wheel coupled to a salvaged car alternator. His system showed students what you can do with a very limited budget and a tiny stream. We also toured the Canyon Industries manufacturing plant in Deming, Washington. Dan New, owner of Canyon Industries, showed us around their production shop. We saw turbines of various sizes that were going to be shipped all over the world—one was going to Honduras, another to Montana.

Dan has a 25 KW AC system that provides some of the power for the facility. We toured the system from intake to tailrace, and talked with him about the special problems of AC systems. It was fun to see a larger system in action.

Down to Business

Thursday morning, the SEI class carpooled to the Omstead property. After everyone arrived, introductions were made, and the class toured the site. We found that Floyd was not as ready as he had agreed to be. The ditch was not completely finished. The power shed was full of stuff. The platform for the turbine wasn't painted. We also later found that there wasn't enough pipe, or enough fittings.

Above: Dan New (center) discusses hydro with SEI workshop students.

Left: Author Louis Woofenden monitoring the flow at the diversion during turbine testing.

We had to work hard just to finish on time. This was good in some ways, because it showed the students how to do an installation quickly. After finding out how much there was to do, we broke into three groups and began installing the system. The intake, penstock, and electrical system were all tackled by different work crews. We did finish, with the group's hard work, and a truck full of tools and parts brought by SEI alumnus John Klemmedson who came to help out.

We Capture the Water

The intake was designed as an in-stream diversion—a small dam in effect. This means that the intake blocks the whole stream, and creates a small pond. The intake structure was made of pressure-treated 2 by 12 lumber, with black plastic sealing most of the cracks. The diversion was divided into two sections, the intake section, which was screened, and the spillway section, where the extra water spills over and returns to the stream.

We used the small dam because local residents said that not much silt or debris comes down the stream in winter. Just above this system is a system with three overshot waterwheels, and we expected that it might

The penstock, still propped over the ditch for ease of gluing, snakes its way down to the turbine.

filter out whatever did come down. Now that the system has been in operation for a few months, it's obvious that we were all mistaken. Floyd reports that the impoundment area fills with silt and rocks, and he has to clean the screen quite frequently. He is now in the middle of designing a better intake system to deal with the actual stream conditions.

The penstock was attached by first cutting four inch (10 cm) holes in the pressure treated 2 by 12 lumber. Then a short piece of pipe was glued to two couplings, one on each side of the wood. We then had a "coupling sandwich," and it was secure. Next we glued on a tee, to which we later attached an air vent.

The air vent prevents the penstock from damage if the intake is suddenly clogged. If there were no air inlet and the intake was clogged, the force of the water rushing down the penstock could cause a vacuum that might collapse the penstock. We also added two cleanouts low in the dam wall.

Penstock

When we arrived at the site, the 450 foot (140 m) long ditch to bury the penstock was mostly completed. It was dug by a backhoe, and it needed to be evened out, and dug a bit deeper in a few places. While some of us worked on the intake and other projects, a few of the students and staff did the required ditch digging. After the ditch was finished, it was about eighteen inches (45 cm) deep.

The crew then laid sticks across the ditch about every five feet (1.5 m) to hold up the penstock, so that it was easier to glue the pipe together. We removed the sticks and lowered the pipe into the ditch before we pressure tested the penstock. The penstock was constructed of ten and twenty foot (3 and 6 m) sections of 4 inch ABS pipe.

Manifold & Turbine

The manifold was built from 4 inch ABS pipe. At the bottom of the penstock, there is a tee. We connected one side of the tee to a 2 inch ball valve. Ball valves were not the best choice, but gate valves in this size are expensive. A ball valve can be closed very quickly. When you close any valve too quickly in a hydro system, you create a surge of pressure at the bottom of the penstock. This is called water hammer.

Water hammer occurs because the water rushing down in the pipe has a lot of force. If you suddenly cut off an outlet for the water to escape, then the water that is moving pushes the water in front of it. Because water isn't very compressible, a lot of pressure builds up. This

Floyd and Frasia's cabin (left) and power shed (right).

can burst joints of pipes, or pipes themselves. If Floyd had bought gate valves instead of ball valves, the potential for water hammer would have been reduced, because a gate valve takes more time to close than a ball valve.

After the ball valve came a nozzle. We cut the four nozzles to different diameters, so that Floyd has more options for how much water to use. The other side of the first tee went to a 90 degree fitting. After the fitting came a short section of pipe, which was connected to another tee. One side of this tee went to a valve and nozzle, and the other side continued to another 90 degree fitting. The manifold continued in the same way to the other nozzles. It was quite a puzzle to get it together properly, and we had to do some cutting and refitting.

Stream Engine

Floyd chose the Energy Systems & Design (ES&D) Stream Engine, which is made in New Brunswick, Canada. The ES&D turbine is a bronze turgo wheel coupled to a permanent magnet alternator. The permanent magnet alternator requires less maintenance than an alternator with brushes, but it is harder to adjust for maximum output.

Turgos can handle more water than Pelton wheels. At Floyd's site, this is a definite advantage, because of his high flow in the rainy season. The head (vertical distance from the intake to the turbine) is only about 30 feet (9 m), and the lowest flow is around 40 gallons per minute. But in the winter, this flow can more than quadruple. Floyd wanted to be able to handle as much water as possible, so he chose the Turgo runner.

Electrical System

The electrical system was installed in one side of a small shed about 20 feet (6 m) from Floyd and Frasia's cabin. The shed was partitioned, with one side for the electrical equipment, and the other side to be used as a

The completed manifold with the ES&D turbine.

wash house. Floyd chose to have only AC loads, so he will be running all his loads through his Trace inverter. Because he is not running any DC loads, his choice of a 48 volt system makes good sense. A higher voltage allowed us to use smaller wire in between the turbine and the power shed, because of the lower line losses.

John Heil from Dyno Battery headed up the electrical crew. He provided expert instruction and design assistance even while under the stress of working with his competitor's batteries. By the end of the first day, the inverter and batteries were wired, and the inverter was providing AC power from the energy stored in the batteries. The batteries are eight Trojan L-16s, and are connected in series to provide 350 amp-hours at 48 volts DC.

We used 3/4 inch (19 mm) plywood for a backboard to mount the gear on the wall of the power shed. The crew mounted the Trace 5548 sine wave inverter, DC disconnect box, and Trace C-40 charge controller on the wall. The AC output from the Trace was connected to a multi-plug outlet mounted on the wall of the power house, since Floyd wasn't ready to run it to the cabin.

Omstead System Loads

Item	*Watts*	*Avg. Hrs/day*	*KWH/ day*	*%*
22 incandescent lights	1,320	2.00	2.64	35%
Fridge/freezer, 11 cu ft	400	3.00	1.20	16%
Ceiling fan	50	24.00	1.20	16%
Chest freezer, 9 cu ft	500	2.00	1.00	13%
Computer	300	2.00	0.60	8%
Toaster oven	1,500	0.25	0.38	5%
2 TVs and VCR	180	2.00	0.36	5%
Microwave oven	1,100	0.25	0.28	4%
		Total average KWH/day	7.65	

The inside of the power shed, showing inverter, DC disconnect box, charge controller, and dump load.

We also installed a Cruising Equipment E-Meter to monitor the system.

The C-40 prevents the batteries from being damaged by overcharging. We ran the output of the turbine through a 20 amp disconnect. This prevents the system from damage if a short or other fault occurs. We then wired the C-40 to dump any excess power into a heating element attached to the wall. The heating element will provide some heat to the battery room and wash house.

Earlier, some of the class had dug a trench between the power shed and the turbine site. The electrical crew laid PVC conduit in the trench. Then they pulled the wires through the conduit, and we were almost ready to test the system.

Putting It All Together

Most of the separate parts of the system were now complete. The electrical system was ready to accept the power from the turbine. The intake was all prepared, and the manifold was assembled. All we had to do to send water down the penstock was to put in the clean-out plugs in the dam. But down at the turbine site, there was still work to do. We needed to connect the manifold to the turbine, install a pressure gauge, test for and fix any leaks, and wire the output of the turbine.

It was quite a job to attach the manifold to the turbine, and not without its problems. To get the manifold on, we had to flex the pipe slightly. After attaching most of the nozzles to the manifold, we tried to bend it too much in an attempt to get it all together, and we broke a nozzle. Luckily, ES&D provides six nozzles with their turbines, so we just replaced the broken nozzle and began again. This time we put it all together with no mishaps.

We added a wye to the end of the penstock above the manifold. From the bottom of the wye we continued the pipe in a ditch, all the way to where the water from the turbine runs back into the stream. On the end we attached a clean-out. Floyd can periodically open the clean-out and let any residue from the bottom of the pipe wash back into the stream. We connected a short piece of pipe to the top of the wye, and connected a tee to it. We glued an adapter and valve to one side of the tee. This is so Floyd and Frasia can tap water from the penstock for irrigation and fire protection.

We glued a 22 1/2 degree fitting on the other end of the tee, and a piece of pipe about three feet (1 m) long. This brought us almost to the manifold. We added one more 22 1/2 degree fitting, and glued it all together. We then drilled a small hole in one of the fittings and threaded the pressure gauge in.

Ready to Rumble!

Then...the time we'd been waiting for. We were ready to pressure test the system. Someone ran up to the intake of the penstock and closed the clean-outs. We left the irrigation water valve open for a while to let the air escape. In a couple of minutes, the penstock was full of water, and the pressure gauge read 16.5 psi. We wired the output of the turbine to the wires running through conduit to the power shed.

Now we were ready to test run the turbine. One of the students held a multimeter, which was set up to measure how much electricity was being produced. The Stream Engine doesn't have an ammeter included. Instead, inside the connection box is a shunt and two test points. It's set up to show you the output amperage by measuring DC millivolts at the test points.

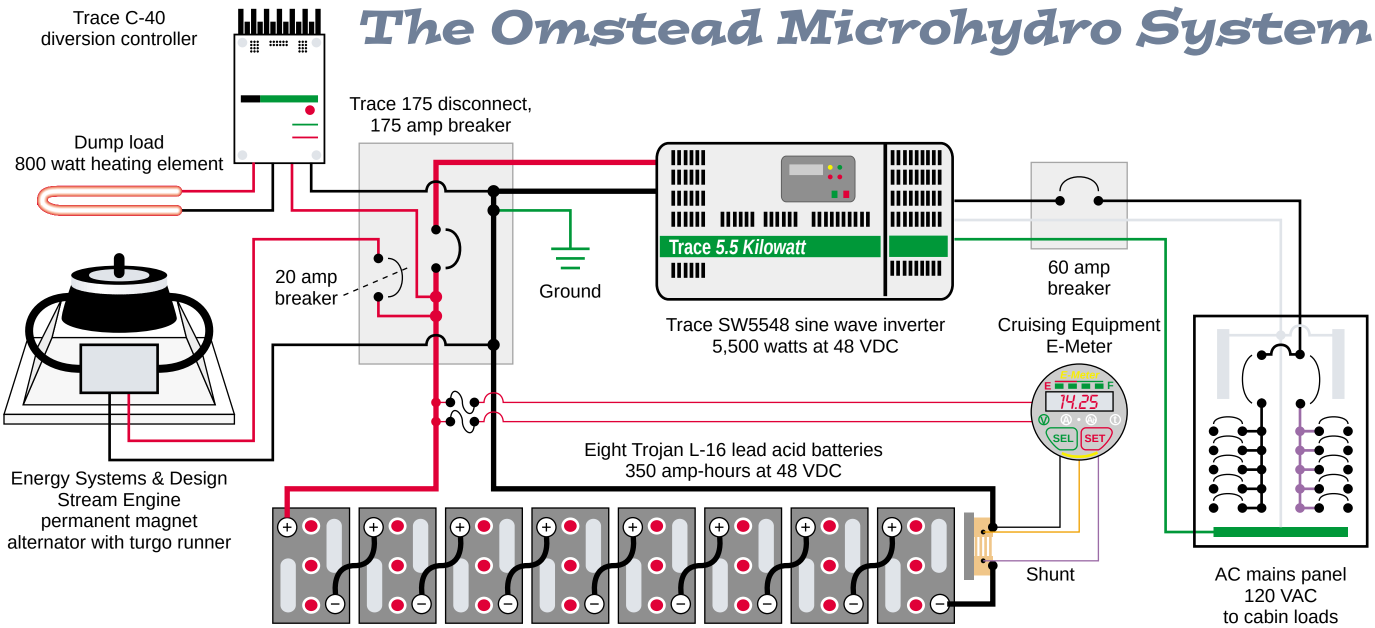
Someone opened the valve. The turbine spun up to speed. It was making power! The meter read 5.8 amps, which is about 280 watts at 48 volts. At this point we all had big smiles on our faces, and we were gathered around, looking at the meter and listening to the hum of the turbine.

We weren't done yet though. We had started the turbine using the largest nozzle, but that soon brought the water level at the diversion down. If we continued to use the water at that rate, pretty soon we'd end up with air in the pipe. If any air is in the penstock, the turbine will still run, but you lose head, and therefore power.

Adjusting Flow

One of the students had a pair of FRS transceivers. So while the turbine crew turned on a nozzle, I watched the

The Omstead Microhydro System



water level at the diversion and reported back to them on the radio. If the water level went down, that meant that we were using too much water, so we tried the next smaller nozzle.

We installed the system in the season with the minimum flow it will see. In the winter, spring, and early summer, there will be much more water, and Floyd will be able to use more nozzles and have more power output. We found that even using the smallest nozzle, the water level was still going down, so we replaced one of the nozzles with a new nozzle cut to a smaller diameter. That did the trick. The water level didn't fall. It actually spilled over the top of the dam a bit, which is just what we wanted.

Adjusting Output

We started working on adjusting the Stream Engine for maximum output power with the smallest nozzle. The Stream Engine has magnets that spin, and fixed coils. The magnets can be moved up and down, nearer and farther from the coils. For any rpm, the closer the magnets are to the coils, the more power is produced. But if the magnets are moved closer, the turbine slows down. To produce power, the turbine has to spin above a certain rpm. The trick is to find a balance between having it too slow and not producing any power, and having it too fast (magnets too far away from the coils) to produce much power.

We didn't have time to do the process thoroughly, but we got the magnets adjusted to approximately the right distance. Just doing it roughly took a long time. First we had to close the valve, and wait for the turbine to stop.

SEI instructor Johnny Weiss holds the meter while system owner Floyd Omstead (left) and students share the excitement of making power.

After two long days of work, remaining SEI students, staff, family, and friends gather for a group photo with the running turbine.

Then we had to loosen a nut that locked the magnets at whatever distance they were from the coils. Then we screwed the magnets closer to the coils. Then we had to tighten the nut that locked it. Finally, we opened the valve and let the turbine spin up.

Then we checked what the power output was. If the power had increased from the last test, we repeated the process all over again, and moved the magnets even closer to the coils. If the power had decreased, we back-tracked and moved the magnets farther away. After everything was adjusted, the turbine put out 2.1 amps at 48 volts, or about 100 watts.

Useful Energy

By this time, it was dusk. We finished up the last minute details, and headed up to the power shed. We plugged in a light, and looked around at our handiwork. We looked at the E-Meter, and saw what the voltage and amperage where. The class went outside, and gathered around. Goodbyes were said, and addresses exchanged. The students drove off into the darkness, tired, but satisfied to know that the job was done, and that they had a good working knowledge of how a microhydro-electric system works.

This system will make a big difference for Floyd, Frasia, and their two children. Floyd reports that for the past two months, he's been running the turbine on three nozzles with an output of 11 amps at 48 volts, or over 525 watts continuous. This gives the Omsteads a significant energy surplus, so they don't have to worry much about what loads they use during the winter.

The hydro system has allowed them to move into their cabin and stop paying rent. It will provide them with ample power year-round. When wind storms take out grid power, it will keep their lights shining when others are lighting candles. If efficient loads are used, it will provide power for them to eventually build and electrify a larger house. The system will help *people,* which after all, is what renewable energy is all about.

Access

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Omstead Hydro System Costs

Item	*US$*
Trace 5548 inverter	4,000
ES&D Stream Engine	1,900
8 Trojan L-16 batteries	1,600
ABS pipe & connections	1,000
Misc. (fuses, wire, breakers, switches, etc.)	500
Electrical conduit & wire, 160 feet	400
E-Meter with prescaler for 48 V system	375
DC disconnect, 175 amp	310
Trace C-40 charge controller	185
Turbine base & enclosure	125
Battery interconnect cables	125
Lumber, 2 x 12 pressure treated	80
Hardware cloth	20
Visqueen plastic sheeting, 6 mil	20
Pressure gauge	20
Dump load (heating coils)	20
Total	$10,680

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