Above: Our house is powered by micro hydroelectric and solar electricity.

The 10 Kinzel/Kingsley Rules for Surviving Micro Hydroelectric Power
(and what the ads and manuals don't tell you)

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In the fall of 1991 we started to build a small, off-the-grid house. Living next to Lake Superior in Michigan's upper peninsula, we knew that a source of electricity to supplement our PV panels would be necessary to get us through our dark and cloudy winter. The tall towers required for wind turbines were quite daunting. A stream flows through our yard, but thinking it viable only out West where the heads were high, we didn't seriously consider hydro power initially.

Attending the Midwest Renewable Energy Fair prompted us to reconsider hydro power and take actual measurements. We consulted with Paul Cunningham of Energy Systems and Design. Now, while our PV panels are an idle piece of art during the long night of December, our hydroelectric turbine produces generous, reasonably reliable power. Now in our third year of hydro power, this satisfactory state has not come without glitches. What follows is a Murphy's Law catalogue of things that will go wrong for any ordinary person attempting to grapple with micro hydroelectric power.

Rule Number 1
Never underestimate your ability to cheat on your measurements.

We measured the flow of our stream using two methods (HP #8, page 17 and HP #15, page 17)

coming up with about 750 gpm in the driest month. Since this was so much more than we needed, an overestimate wouldn't have caused much of a problem. Measuring head was another story. We used a 50 foot garden hose, stretched out in the stream bed. After a flow through the hose was established, we would raise the downstream end. The distance from the stream surface to the hose end was then measured, giving an estimate of the head over that section of the stream. The process was repeated until the portion of the stream from the proposed intake to the turbine was measured. Errors are easy to come by. There is at least a 2 inch difference between where the flow just begins to stop and where it actually quits. Inertia tends to accentuate this error. The stream surface is usually rippled. Of course, we erred on the side of more apparent head. We were off two feet over the 400 feet of the stream bed. We thought we had 17 feet of head when the reality was 15 foot of head.

This error was compounded by minimizing the height above the stream bed that the turbine must be placed so as not to be endangered by fluctuating water levels — allowing us to pretend we had a foot of head more than we actually did.

Rule Number 2
Never underestimate the ability of the technical elite to dazzle and befuddle us technological dummies.

Rule Number 2A
Never underestimate the ability of the technical elite to overestimate the knowledge of us technical dummies or to take for granted critical issues which seem obvious to them because they work with them daily, but are anything but obvious to us.

Having decided that our site had potential, we called Paul Cunningham at Energy Systems and Design, who after hearing of our site said something to the effect, "Whoa, you'll have so much electricity that it will be too cheap to meter." (Reminding me of the infamous promise of atomic power.) He subsequently launched into about 500 calculations in the next few moments, occasionally asking a question in some language faintly reminiscent of English. Having only the vaguest idea of the meaning of the questions and not wanting to appear too foolish, we gave answers we hoped would please him. The upshot: a shiny new turbine with the cutest little runner (water wheel) appeared in our garage a few weeks later.

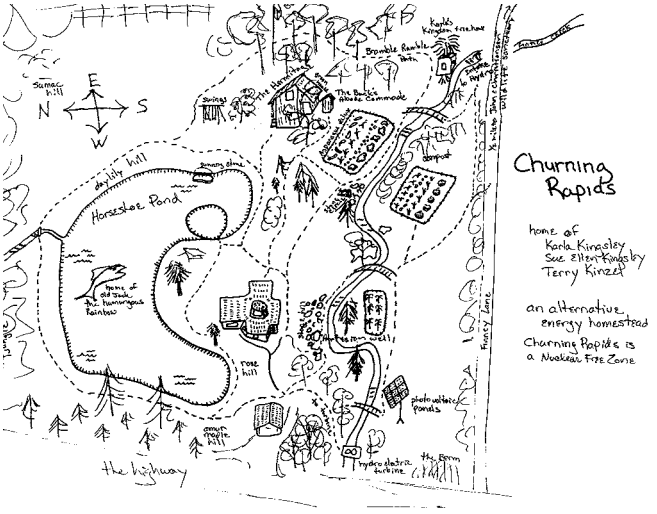
Rule Number 3
Never underestimate friction.

Our site (using our somewhat inflated values for head) called for a FAT (Ford Alternator Turbine). The turbine

Top: The intake impoundment and spillway. Water is filtered for debris and fed into two 4 inch diameter pipes.

Center: The ES&D microhydro turbine is fed with two 1 inch diameter nozzles.

Bottom: A close-up view of the turbine.



used two 3/4 inch diameter nozzles, delivering 75 gpm and yielding a predicted output of 90 Watts. Given the projected run of 300 feet (underestimated from the actual 350 feet — see Rule #1), 17 foot head, and 75 gpm flow, a 4 inch drain pipe was chosen to deliver the water. This was split just before the turbine and stepped down to two 1.5 inch pipes attached to the two nozzles. The turbine was bolted to a cement block sitting about two feet above the stream with a 6 inch stove pipe running through it to handle the water egressing from the turbine. Since there was only a single 4 inch pipe delivering water, it seemed obvious that a 6 inch pipe for the tail water would be sufficient. After some minor missteps, the water was hooked up and the wires connected in approximately the correct order. We let her rip, anticipating the glorious vision of the ammeter plunging off the scale as power surged through our circuits.

In fact, it was hard to tell that the analog ammeter in the turbine moved at all. However, using a digital ammeter and voltmeter, it appeared that the turbine was producing 1.2 Amperes at 13.0 Volts or a dazzling 15.6 Watts. Despair! Grief! Frantic calls! "Describe your set-up again." "What about egress?" "You need absolutely free egress so that friction won't slow down the wheel!" (See Rule #2A.) So we modified the system to lower the turbine to about one foot above the stream and gave it free egress, bringing the output up to 45 Watts. The turbine proved very reliable, causing no problems throughout the winter. The below predicted output was not a problem since there was still construction going on and we were still partly connected to the electric utility grid.

Rule Number 4

Never underestimate the capacity of technical dummies to learn and be helped by considerate, one-on-one, face-to-face consultation.

The next summer, we returned to the Midwest Renewable Energy Fair, after having a year of generally positive experience with our turbine. We were still vaguely unhappy that it was producing only about half the predicted power. After a delightful consultation with Don Harris, we made the following modifications:

1. Increased the nozzle size to two 1 inch nozzles (included with the original order).
2. Laid a second 4 inch pipe to decrease friction loss in the pipe, especially with the increased flow through the larger nozzles (see Rule #3).
3. Replaced a section of line that had been squished a bit by a gravel truck driving over it (see Rule #3).
4. Lowered the turbine to 6 inches above the stream bed.
5. Raised the dam at the intake site about 8 inches. A board across the stream creates a pool deep enough to cover the screened intake.

The result: 115 Watts of continuous power (2.75 kiloWatt-hours daily) for the past 18 months (with a few dramatic interruptions).

Rule Number 5

Never underestimate the power of water to wreak havoc.

A 4 inch pipe under only 7 or 8 pounds of water pressure doesn't sound very threatening. However, when a joint pops free at the last fitting before the turbine with you being the only object between an ocean of pressurized ice water and an expensive piece of electrical equipment, the experience is distressing.

Our intake is screened by hardware cloth and window screen in a wood frame into which the two 4 inch pipes fit. During most of the year, it requires no attention. However, during the spring melt and the fall leaf season, it periodically needs to be cleaned. A grass rake handles this task. However, during the times the screen is occluded with leaves, the columns of water in the pipes create a huge suction. On more than one occasion, the suction has collapsed the box or sucked the screen into the pipe. Always build this part of the system stronger than you ever dreamed necessary. (See Rule 2A.)

It rains, the stream surges, and the dam you thought was stronger than Grand Cooley washes out — a scenario guaranteed at least once. Although inconvenient, this allows opportunity to fulfill every little boy's dream of playing in streams.

A corollary here is: Don't Get Greedy. After coming to fully appreciate the importance of head and pressure, we tried to squeeze the most power possible out of the

Above: Karla, Terry, and Sue Ellen.

Top Right: Our Independence Day party with watermelon relay in progress.

Bottom Right: Churning Rapids during the winter.

turbine. We moved it as low above the stream as seemed safe. The same “once in a decade” fall storm that washed out the dam caused the stream to surge within millimeters of the turbine. Being away for the night (Rule #8), we only realized this later. Fortunately, during the winter, when we need the most power from the turbine, the stream is very steady. During the other seasons, the PVs produce so much power that the turbine can be raised safely out of harms way.

Rule Number 6
Never forget that even moving water freezes.

Water abhors discipline. The board we installed to raise the intake pool is buried in the stream bed. Water flows over the top of the board. Last winter, when the mercury hit -20°F, the top of the pool froze over, and the water chose to dig a channel underneath the board. The intake was left high and dry. We filled burlap bags with stones to span the breach and it held for the rest of the winter. No fingers or toes were lost to frost bite.

Having watched the stream for many winters, we knew it never got more than a crust of ice. Since most of the pipe was buried, we were not too worried by the prospect of freezing. The first winter, we lightly insulated the small portion that was exposed. Our actions were somewhat validated when we experienced no freezing problems. We went into the second winter with a modified system. With two 4 inch supply pipes, the water flowed more slowly. Also, the turbine nozzles are on opposite sides. So, one pipe is a straight shot while the other is forced to make a 180 degree loop to reach the back side, slowing the water further and exposing more pipe to subfreezing air. That winter was the coldest in many years. After our third night of 25 below, with highs reaching all of -15°F, we awoke to an output of about 50 Watts. Sections of the long and winding pipe were frozen. We were resigned to the idea that the entire pipe would now freeze solid and wouldn’t thaw ‘till summer. The next two days were above zero and for reasons that remain completely obscure to us, the pipe thawed. We beefed up the insulation in exposed portions and maintained full power for the remainder of the winter.

As a consequence of this experience, we modified the pipes last summer. Both delivery pipes each made a 90 degree turn and were stepped down from 4 inches to 2 inches in diameter before the bends. We reasoned that the water would be moving faster through the 2 inch pipes and would be less likely to freeze. Unfortunately, this resulted in a 15 watt loss of power (see Rule #3). Consequently we went back to the original design and put a bit more insulation on when the snow began to fly.

Rule Number 7
Never forget that, for most of us, electricity moves in mysterious ways.

The first year, after we got the output up to 45 Watts, we were troubled by the fact that the voltage at the turbine always read about 13.5 to 14.0 Volts. This did not seem high enough since our PV panels were producing 17.8 volts and we were using NiCd batteries (since replaced with lead-acid) with a fairly high voltage. Although we had plenty of power (our 120 vac circuits were still grid-connected at that time), we weren't quite sure where the electricity was moving. The low voltage was suspect in the below-predicted output. This was before we really believed Rule #3. Several calls to New Brunswick regarding this matter enriched Bell Telephone and re-confirmed Rules #2 and #2A. We returned the turbine. Paul stated that it worked fine and he couldn't understand why we were upset about the voltage. He managed a rapid turn-around time, paid for return postage, and installed a new, more efficient runner—all at no charge. Eventually, we came to realize that the open circuit/no load will be quite high, while the *working* voltage will always remain about 0.5 Volts higher than that of the battery bank. The electricity always flows in the correct direction. Why this is so remains a mystery to us. By the way, why is the sky blue?

Rule Number 8
Never will your hydroelectric system need attention when it is convenient.

This hardly needs elaboration, but be especially vigilant around the times you have purchased expensive, nonrefundable airline tickets — The System Knows.

Rule Number 9
Never will any local contractors, local electricians, or your friends know enough about your system to easily solve a problem.

In dealing with a problem, a mechanically-oriented and long-standing friend is your best bet. A corollary to this rule is: tell a house-sitter how to read the meters and how to shut the system off when there's trouble.

Rule Number 10
Never is the power output of your hydroelectric system affected by the phase of the moon or your menstrual cycle.

Check the output at least daily; it will be monotonously steady. If the power has fallen off even a few Watts,

Churning Rapids Fact Sheet
Property: 2.7 acres
House size: approximately 750 square feet
Builder: primary, Brian Maynard; secondary Dan DePuydt and Dave Bach
Design: Terry Kinzel
Energy Production
Photovoltaics: 8 Solarex MX60 PV modules mounted on a Wattsun tracker producing 480 Watts (28 Amps at 17.4 volts in full sun)
Hydroelectric: Energy Systems and Design; Ford Alternator Turbine with 16 feet of head, flow of about 75 gpm producing 115 Watts (9.4 Amps at 12.2 volts, continuous)
Energy Storage: Six L16 lead-acid industrial batteries in series and parallel to give about 1050 Amp-hours at 12 volts
Energy Management: Enermaxer charge controller with two 15 Amp hot water resistance coils to preheat water — in summer providing a substantial portion of our hot water
Inverter: Trace 2012 (has trouble with the clothes washer —inquire for details)
Metering: Cruising Equipment Amp-hour Meter, two SCI Mark III meters measuring battery voltage, Amps in from PV, Amps in from hydro, Amps out through DC junction box and Amps out through inverter
Heat Source: Reliance high efficiency wood stove with Olympic catalytic propane heater back-up
Hot Water: Enermaxer preheat, Aquastar instantaneous propane heater
Well: 362 foot artesian well; Flowlight booster pump to pressurize the system
Appliances: Sun Frost 12 cubic foot refrigerator, Sun Frost 10 cubic foot freezer, Caloric propane range and oven, Kenmore front loading washer
Lights: Electronic ballast compact fluorescents, and 12 volt halogen incandescents
The house is a modified superinsulated design (not completely air-tight and too much window area for maximum efficiency). All glazing is high performance —mostly Anderson windows
There is too much plumbing, partly due to the two-part development of Churning Rapids. The showers use low flow heads. The toilets are Kohler 1 gallon flush connected to a standard septic system and drain field. The Buck's Adobe Commode Composting Outhouse near the garden gets much use.
Other Features: The Hermitage is a guest house/retreat which is tucked into the rafters atop the greenhouse and sauna with dressing room. Pond, veggie gardens, flower gardens, bitsy woods, and rambling paths.

don't look to the moon or consult your calender looking for the reason. Rather, prepare to get wet.

Conclusion

This has been a summary of our experience with our micro hydroelectric turbine. Since we tried to describe some of the pitfalls that may be experienced by people of ordinary skills, it may seem that we are negative. This is not the case. While microhydro is not as simple (for the end user) as plugging into the grid, we have, with help, been able to solve each problem. With a modicum of maintenance and trouble shooting, microhydro has provided us with a generous supply of electricity and allows us to live very comfortably disconnected from the grid. Our batteries have it easy. They are never deep cycled. While most of the technical people we've dealt with suffer from the truths of Rules #2 and #2A, the equipment and service we received from Paul Cunningham were excellent. The advice from Don Harris at the Energy Fair proved invaluable. We would not hesitate to work with either of them in the future.

Access

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