240 vac Direct Drive Hydro

John Hermans

Above: John and Robyn with kids Ben and Jill over the tail race and main shaft.

For seven years, my family and I have been deriving 100% of our electrical energy needs from a 240 vac alternator driven by a low head, axial flow turbine. During this time and the years leading to its development and installation, I read many articles on micro hydro electrical systems.

It is apparent that in recent years the number of micro-hydro installations have increased. This is due to their higher efficiency of operation and the availability of smaller, less costly units. These are primarily designed for constant battery charging. I am always intrigued to read of an installation that has a pure 240 vac output, but it is quite rare to find such an article, thus I am prompted to write this one.

Site Selection

Of the hundreds of existing micro-hydro installations along the east coast of Australia, very few would readily adapt to a 240 vac output due to the small volume of water on which they operate. But, there are a large number of potential sites that are suitable for 240 vac which have low to medium head (1 to 6 meters) and flow rates which are considerably higher. This situation usually requires a river frontage property as opposed to a creek. It is the Nicholson River of East Gippsland, Victoria, Australia which provides us with just that: a low head (1.2 meters) but high volume (100 to 2000 liters per second).

The Weir

Perhaps the only real obstacle to the construction of a similar system is the ability to build a water impermeable concrete and rock wall. This wall is required to allow water to enter the penstock (the piping to the turbine). It should not only resist flood damage, but should not initiate erosion problems in times of flood. Its potential to be undermined by water under pressure must be avoided. Such a site should preferably have a monolithic rock base for the majority of its length. The use of low level walls across rivers gives rise to minimal ecological impact. It is evident from my own installation with a small fish ladder that aquatic life is still free to move up and down the stream. This is most certainly not the case only 1 kilometer upstream, where there is a 10 meter high concrete weir built to supply water to the nearby coastal towns.

Above: An upstream view of the hydro installation and the 1.2 meter high weir. The "power tower" in the foreground houses the alternator and pump.

Low head installations are often subject to annual submergence by local flooding. In my case, this has minimal impact on the mechanical components. My only preparation for such a submergence is to remove and carry the alternator to high ground. This is a small price to pay for the high returns we receive from this system.

Providing an installation with high flood resistance can be achieved if some basic principles are used. To increase flood resistance:

- Use high strength concrete with water-proofing admixes at rock interfaces and include multiple drilled-in-place 12 mm rebar anchors.
- Use large diameter stainless steel anchor bolts with epoxy resins.
- Use heavy steel construction.
- Use pipe bracing.
- Use metal plate water and debris reflectors.
- Galvanize and epoxy paint steel that is frequently submerged.
- Position mechanical components out of line of flowing debris.

It is very possible for an entire system to be swept away. This threat has undoubtedly prevented many people from going ahead with their installations. On one occasion, I had four meters of flood water over the top of the alternator "power tower" for two days. Yet, my only chore after the waters subsided was to pump fresh grease into the bearings in order to displace water. After 20,000 hours, the running gear has been submerged at least six times and the bearings have been changed only once.

Below: Turbine (not running) outlet showing PTO shaft with CV joints from an old Subaru.

Pumping Water

An additional benefit of my turbine is its use in driving a Grundfos multi-stage centrifugal pump. This pump delivers 1 liter per second to a 220 thousand liter concrete tank situated 100 meters vertically above the river. This is achieved by taking the v-belts off the alternator and flywheel and placing them on the pump.

Flywheel Use

The constant output of the 4 kVa alternator is relatively small (1.2 kVa) but is adequate for all our household and workshop requirements. (The exception is my welder, which is diesel powered. Putting out 250 Amps at 40 Volts does not come easily in many alternative energy systems). The use of a 30 kilogram, 400 mm diameter steel flywheel, spinning at 50 revolutions per second, is invaluable for starting induction motors up to 1.5 hp. Its stored energy is transferred smoothly to the alternator when sudden heavy loads are applied. This leads to minimal voltage and frequency drop, eliminating lighting flicker.

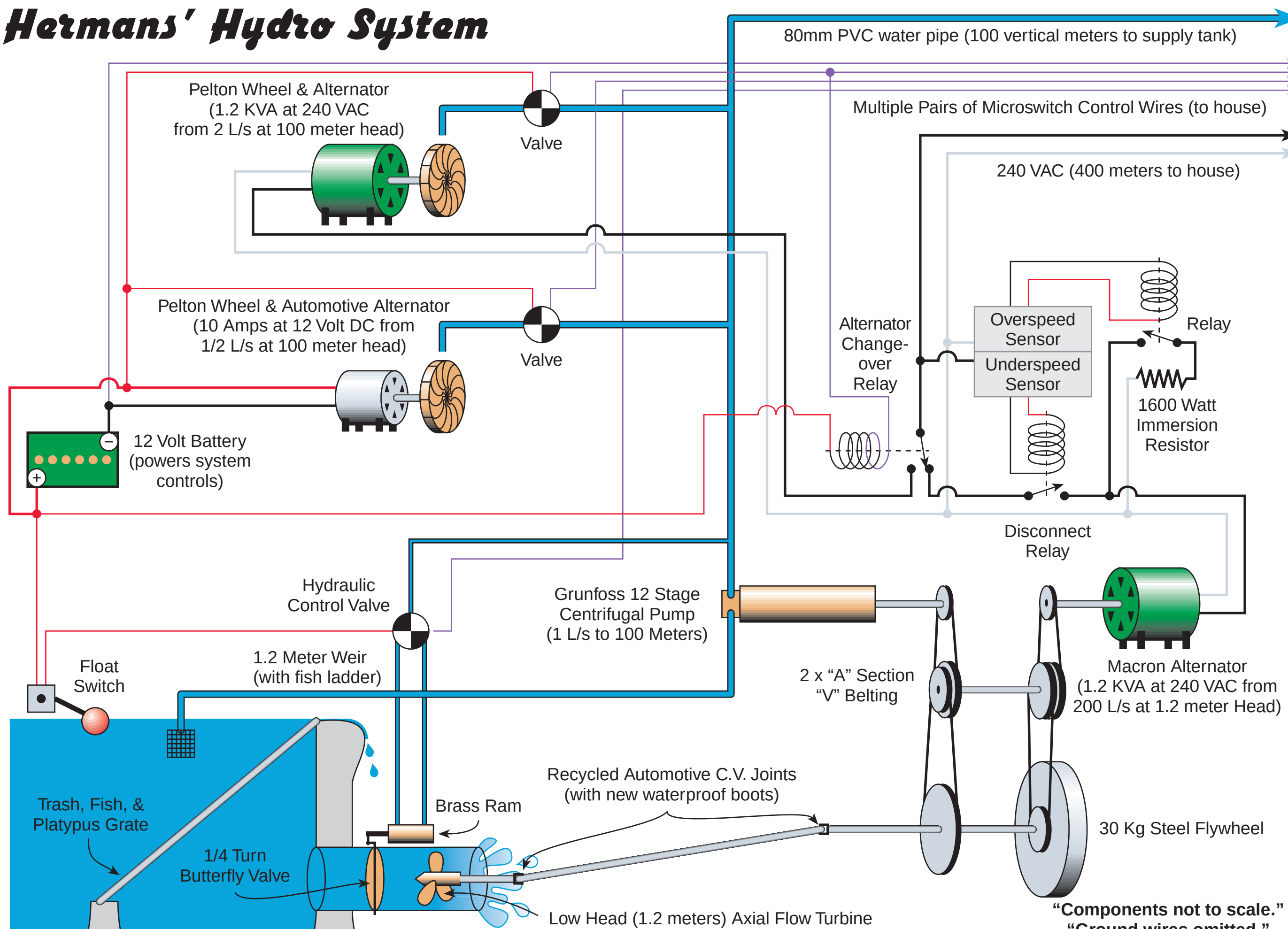
Design for Low Flow

The axial flow water turbine does not lend itself to throttling via reduction of the water flow through the turbine pipe. 200 liters per second is required to run the turbine. In summer, and other times of flows less than 200 liters per second, a turbine shutoff valve is

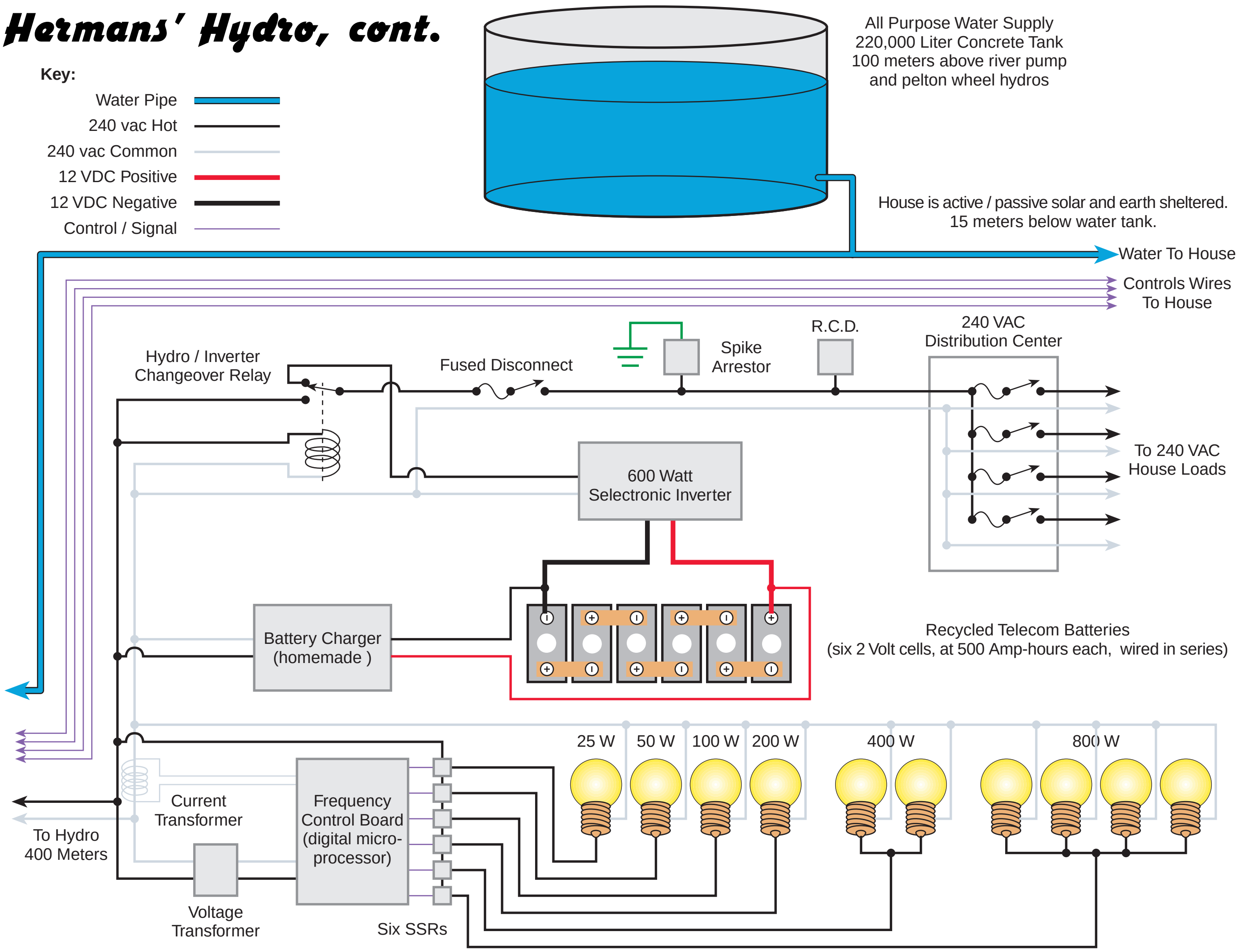
Above: The Power Tower houses the alternator (upper left), the 30 kg flywheel (lower left), and the pump (lower right).

Above: The other side of the Power Tower showing the drive shaft, primary step-up belting, and the pump (in pumping mode).

Hermans' Hydro System



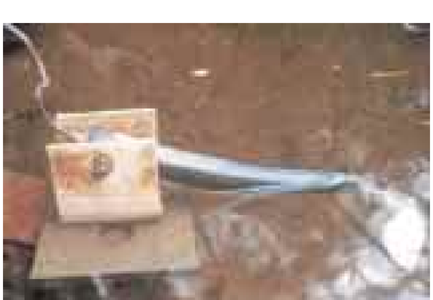
Hermans' Hydro, cont.



essential. A falling weir water level is a common problem in many installations and is overcome in my system in two ways. First, I use a bilge pump float switch in the weir water supply. This opens the control switch for the turbine valve when the water level falls approximately 70 mm. The control switch closes the turbine valve in the penstock, shutting the system down. When the water level is restored the switch closes to start the alternator spinning again. If the turbine takes 200 l/s to run constantly, but only 160 l/s was available, then the alternator-turbine would have a duty cycle of 80%, running 20 minutes on and 5 minutes off.

A preferred method of dealing with variable flow rates is to use a cross-flow turbine which can be throttled by either a pivoting guidevane or a shutter arrangement across the water jet. This throttling ability, and the ease of home manufacture, makes this turbine a first choice for many low head installations.

To counter low flows, we also use a small battery bank and inverter. Our TV, stereo, and computer are all



Left: A home-made mercury bulb float switch controls the butterfly valve that adjusts flow through the turbine.

Right: A hydraulic ram, driven by water pressure from the tank 100 meters higher, actuates the butterfly valve.

Above: Control and meter box with lightbulbs used for diversion loads.

permanently wired to a 600 watt inverter. All other loads are automatically switched over to the inverter when the alternator switches off by either the float switch or manual controls. A slight flicker of the lights at night is all that is evident. In times of low river flow, most of my 1.2 kVa goes into battery charging.

Frequency Control

The heart of this micro-hydro installation is the electronic "stand alone computer" frequency control board. For four years, I had a very crude electronic load control which shunted unused power into either 400 or 800 watt dummy loads. This system was less than adequate on many occasions. My quest to find a more appropriate controller was not an easy one. After much searching, I chanced upon an electronic control board which not only works well, but leads the technology world-wide. I now have the first installation in Australia.

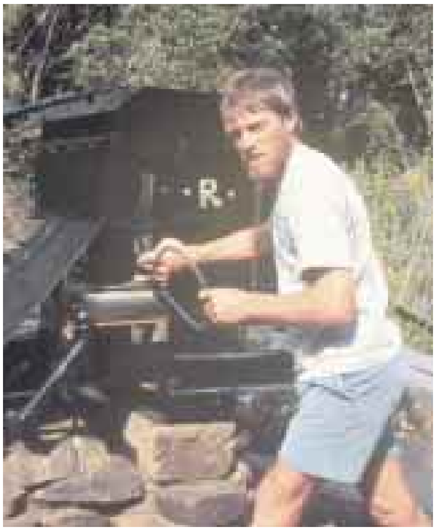
An Australian electronics engineer designed the frequency control board in conjunction with Appropriate Technology for Communities and the Environment (APACE) located at the University of Technology Sydney (UTS). Its development began when APACE, an Australian government aid program, began installing 240 vac micro-hydro systems in the Pacific Islands. UTS has been using this control board as an educational tool for senior and post graduate students for over ten years. It has undergone thousands of hours of testing.

The circuit board itself is only 150 mm square. It uses a digital microprocessor incorporating a special algorithm to maintain alternator frequency to within one cycle per second on either side of 50 Hz. The software resides in ROM and the unit is programmed to handle the high speed response required for low kW output micro-hydro systems. For over three years, this unit has proved faultless in my system.

The control method maintains full load on the alternator by matching the power output to the load. This is accomplished by monitoring the frequency for variation and switching dummy loads.

In my case, the dummy loads are six incandescent light bulb sets: 25, 50, 100, 200, 400, and 800 watts. The digital microprocessor determines which combination of the six loads to have on in order to maintain 50 Hz, and hence 240 volts. There are 64 combinations available, from 25 to 1600 watts in 25 watt increments. Thus, if the house is using little of the generated power, say only 250 watts of night lighting, the controller will make

Left: The frequency control board, made by the University of Technology, Sydney, keeps the ac waveform within spec.



Right: John changes belts to switch the hydro from alternator to pump.

qty	*item*	*cost*	*%*
1	Concrete water tank	$4,000	28%
1	240 V pelton wheel/alternator	$3,000	21%
450	meters of 80mm PVC Pipe	$1,500	10%
2	Macron 4 KVA alternators	$1,300	9%
400	meters of paired cable	$1,200	8%
1	Grundfoss centrifugal pump	$1,000	7%
1	Frequency controller	$1,000	7%
1	Tower of Power	$600	4%
1	Concrete weir	$500	3%
1	12 V pelton wheel/alternator	$200	1%
	total	$14,300	

up the difference. It will turn on the 50, 100, and 800 watt dummy loads to produce the total 1200 watt load requirement. The load adjustments occur at the rate of ten per second, in 25 watt steps, which at times gives the appearance of a disco going on at the rear of my garage. The light bulbs still manage a few years of use.

Damage Control

Included with my control system is a separate circuit board which is mounted close to the alternator. In case of control board or power line failure, it senses potentially damaging under and over frequency. It then responds by shutting down the turbine-alternator unit.

Access

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Micro-hydro governor available from J. A. Brebner PL, 74 Second St., Ashbury, N. S. W. 2193, Australia
E-Mail: pfa@ozemail.com.au
Web: www.pactok.net.au/docs/apace/home.htm