Small Hydro power Siting

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There are small streams occurring over much of the countryside. Perhaps you are wondering if a brook in your area is suitable for developing into a power source. The following is intended to show the procedure I used in my own case to arrive at solutions to various problems. Hopefully, discussing the thinking involved will provide some insights.

A small scale water power system requires a more specific site than either a wind or photovoltaic one. You do need to have some flowing water. On the other hand, it isn't necessary to have very much, or much pressure, and it doesn't have to be very close to the point of use. My situation will illustrate this.

Here in the Canadian Maritimes it is difficult to go very far without finding some type of stream. I live in an area of rugged topography which enhances the water power potential. My house is located near a brook that most times of the year has a fairly low flow rate. There is normally little water in the stream above the house while water from springs which come to the surface steadily increase the flow as the water runs downhill.

One logical place for the intake and beginning of the pipeline is near my house. Although flow increases further downstream, the slope decreases. Near the house the brook drops around 8 feet for every 100 horizontal feet. So running a pipeline downstream 1,000 feet produces a combined drop or "head" of 75 feet. This looked like a reasonable place to start although the site permits running a pipeline 3,000 feet before the brook meets another one running almost level.

Polyethylene pipe was purchased (in 1978) and simply laid on the ground. A small screened box serves as the intake and was set in the brook with a "dam" of earth and rocks sufficient to raise the water level about one foot. At this site, the maximum power will be produced at a flow rate of about 20 gallons per minute (GPM). This is the point where the dynamic (running or net) head is equal to two thirds of the static head. So there will be 50 feet of net head at the end of the pipe when the water is running with a suitable nozzle at the end.

Any increase in flow will result in a decrease in power available due to increased pipe friction losses. Right away then one third of the precious power potential is lost. At lower flow rates the pipe loss decreases which results in an increase in efficiency as flow decreases.

So why don't I use a larger pipe? Well, it costs more and sometimes 20 GPM is all there is in the brook. Also a larger pipe would aggravate the problem of freezing at low temperatures with no insulating snow cover. This is because the residence time would increase with larger pipe.   The water entering the pipe is (slightly) above freezing, in my case, and cools as it travels along (when temperatures are very low).

So why don't I bury it? Yes that would be nice and hopefully I will when I can afford that and larger pipe too. It is a case of the shoemaker being inadequately shod as I content myself with the present system. Besides, it has spurred me on to other possibilities that we will look at later in future articles.

Back to the 20 GPM at 50 foot head. A 3/8 inch diameter nozzle is about the right size for this, giving 19 GPM According to the spouting formula the velocity of a jet of water will be:

V = Ã2gH = Ã2*32.2*50 = 56.7 ft./sec.

g = 32.2 feet/sec/sec (acceleration of gravity)

H = head expressed in feet

How much potential power is this? A U.S. gallon of water weighs 8.34 lbs. and the flow is 19 GPM; then 8.34 lbs. per gallon X 19 gallons per minute = 158 lbs. per minute. Now, 158 pounds of water per minute falling 50 feet has 7,900 foot-pounds/minute of energy (simply multiply the factors). Conversion to horsepower is accomplished by division by 33,000., thus 7900/33,000 = .24 horsepower. Since 746 Watts of energy is equivalent to one horsepower, .24 hp. X 746 Watts per hp. = 179 Watts of potential squirting out the nozzle. This means that the potential power was .36 horsepower or 269 Watts before going through the pipe. Since nozzles tend to be very efficient not much loss is expected. But keep in mind that every time the energy goes through a change, power is lost. All right, how about a 9 Watt loss to make an even 170 Watts. This may appear a little sloppy. But you must realize that these systems do not have to be very precise-- they are quite forgiving. Also many of the measurements are difficult to determine with high accuracy. So close approximations are sufficient.

Thus far things are reasonably straightforward - a pipeline with a nozzle at the end. Now what? Conventional practice would suggest some sort of impulse turbine such as a Pelton or Turgo. It would also be possible to use a reaction machine. It would have to resemble one of those spinning lawn sprinklers rather than say, a propeller type. This is because of the very small nozzle area. The impulse type looked easier to build.

At this site it is necessary to send the power back upstream 1,000 feet to the house. I wanted to use 12 VDC and wanted some way to transmit the power other than the very large wire that would be required at this voltage.

In the spring, when the flow in the brook was very high, various 12 VDC generators were operated with the pipeline ending near the house. But this could only be temporary, as ways of solving the transmission problem had to be discovered. Of course using wires wasn't the only possibility. I could always charge batteries downstream at the generator and then carry them up to the house. Or perhaps a reciprocating rod kept in tension could be used to transmitted the power. But all things considered, producing electricity at a voltage higher than 12 VDC looked the easiest.

I thought generating AC electricity at 60 Hz. like regular commercial power would permit using standard transformers and make it easy to change the voltage. For this I bought a "Virden Permabilt" 120 VAC generator. This produces 120 Watts rated out put and 60 Hz. at 3600 RPM. These machines are reworked DC auto generators with rewound field and rotor with a slip ring and brush to carry the output.

An impulse turbine should have a surface speed of about half the jet velocity. So at the 56 feet per second a turbine wheel slightly less than 2 inches in pitch (hydraulic) diameter is required. This is a little on the small side but I did make a Turgo wheel of this size so the rotational speed would be right for direct drive. Yes it's possible to use speed increasers with a larger turbine but I didn't think there was anything to gain and only power to be lost. It turned out that the alternator would not generate 120 VAC at a low power level. The field required 10% of the rated 1200 Watts output to put out 120 VAC regardless of the load. Therefore a lower output voltage was necessary to properly balance the system. It was determined that under the site conditions an output of 24-25 Watts was required to be in the correct ratio:
120 VAC/10 Amperes = 24 VAC/2 Amperes or 48 Watts.

Now you are probably wondering how come only 48 Watts is being produced. Well that is what that combination of turbine and generator put out. And this isn't the end either. Next the juice went through a 25-110 volt transformer, through 1000 feet o f 18 gauge wire (two strands), another transformer down to 12 volts and then through rectifiers to give DC. In the end only 25 Watts or about 2 Amperes actually found its way to the battery.

This setup didn't last long enough to make many improvements. It was hard just keeping it alive. The alternator used only one slip ring. The other conductor was the bronze tail bearing! Both items had limited life under 24 hour service. Besides the efficiency was low anyway.

INSERT HYDRO ILLUSTRATION

I still needed a reasonable system. At least one with a longer life. In the next attempt a 4 inch pitch Pelton Turbine was cast in epoxy using a silicone rubber mold. This directly drove a car alternator with a rheostat in series with the field to adjust the output. Transformers (3) were connected to the three phase output to raise the voltage for transmission with the (now) 3-18 gauge lines. Then a similar set of three transformers is used at the house to lower the voltage and a rectifier to make the DC conversion. About 50 Watts was still generated (4 Amperes 12 volts) but more made it into the battery--about 3 Amperes. The reason for this is the automotive alternators have more poles (12 Ford, 14 Delco) and generate at a higher frequency. This improves the efficiency of small transformers even though they are "designed" to work at 60 Hz. Now the system has an efficiency of around 21% (36 Watts/170 Watts) using the power available at the nozzle as the starting point.

Three Amperes in a 12 VDC system doesn't sound like much. But this is sufficient to run the lights, a small fridge (Koolatron) and a tape player-radio. My house is small and so are my needs. There was sometimes even extra power and I could run Christmas lights or leave on things just to use the extra power.

At some point it occurred to me that I might generate more than electricity if I could produce turbines for others in a similar situation. Peltons were made first for sale. Originally these were made of epoxy and later of a high-strength and abrasion resistant Polyurethane. This endeavor busied me some but it soon became apparent that to survive doing this sort of thing would mean producing complete generating units.

Turgo turbines looked more reasonable than the Peltons for this, due to their greater flow handling capability for a given size. Using a 4 inch pitch diameter turbine wheel allowed as many as four one inch diameter nozzles to be used. This resulted in a very versatile machine.

The first production models used automotive alternators (Delco) since they are inexpensive, dependable, available and most people wanted 12 VDC output. But these couldn't operate with heads of less than 20 feet or so. Also the efficiency of these alternators is in the 40-50% range and I thought there was room for improvement.

Back in the R and D department, work was proceeding to develop a better machine. The Turgo turbines operate in the 60-70% efficiency range. These are made in re-usable silicone rubber molds. This placed certain constraints on their design and so limited the efficiency. But other tests showed there wasn't much to be gained by changing the shape of such a small wheel. However, the generators used so far had efficiencies in the 50% range or less. They also had electric field coils which made for easy adjustment of the output but also took part of the output to operate. It looked like the use of a permanent-magnet (PM) field would be a help and could make operation at very low-heads feasible. Yes, DC motors with PM fields could be used as generators. But my experience with machines where brushes carried the full output was disappointing. Longevity was a problem -- remember these are going to run 24 hours a day. If alternating current could be generated then transformers can be used to alter the voltage to suit the site.

It is well established that the most efficient generator type, especially in small sizes and at low speeds, is the PM-rotor alternator. Just like a bicycle generator. There is also nothing to wear out besides two ball bearings. That would be a feature and a half.

After a few tries, standard induction motors were used by keeping the stators and building new PM rotors. This produced a machine capable of generating power with an efficiency of over 80%. Standard 60 Hz. AC output was possible at 1800 RPM for these 4 pole machines. Experience suggested that frequencies of 50-400 Hz. would operate standard transformers quite well. This, combined with the recommended output wiring, produced a machine able to generate almost any voltage.

So how is it looking back at my site? Using the new PM rotor alternator about 100 Watts of power is produced. This is an efficiency of 100 Watts/170 Watts or about 59%. Dynamometer testing of the alternator shows it has an efficiency of 85% at this condition which means the turbine is running at 69%. Now 120 VAC is generated so no transformers are used at the generating site. The same transformer set used with the Delco installation is used at the battery end. About 6 Amperes are delivered to the 12 volt battery. This gives an overall efficiency of 72/170 or 42% water to wire (water to battery?).

With this system appliances can be run directly off the alternator output as long as this requirement is less than the available power. This creates a hybrid setup that produces both 120 VAC @ 60 Hz. and 12 VDC. A future article will discuss how to deal with more difficult sites.