More Small Hydroelectric Generators

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Compared to other methods of electricity generation, the advantages of hydroelectric generators are well known. In the U.S. hydropower is cheaper than all other ways of creating electricity from coal, oil, natural gas and nuclear reactors. This is primarily the result of the absence of fuel charges, but also because of the trouble-free long life of the sturdy turbine plant. One of the earliest major American power plants of any kind was the hydroelectric facility built at Niagara Falls. It is still in operation 100 years later.

In 1950 about half the U.S. electricity demand was satisfied with gravitational energy, converted to kinetic energy and extracted from ordinary water with turbines. Now at the beginning of the 21st century the hydropower fraction has fallen to 15%. The reason for this will be found in the rapid expansion of electric power consumption due to, first of all, the increase of the population and, secondly, lifestyle improvements afforded by the ready availability of plenty of electric power. No large new hydroelectric plants could be built in the U.S. during the second half of the 20th century, as all suitable geographical locations had already been developed. In general, smaller plants were not economically competitive with fossil fuel burning generator stations. Fifty years ago, the creation of atmospheric pollution was not a factor in the choice of energy sources. Hence the search for promising small hydroelectric plant locations came to an end.

Today we are prepared to pay a premium for environmentally friendly new energy. For example, take the large off-shore wind farm to be built in Nantucket Sound (Massachusetts). It will sell electricity in the Cape Cod area for about twice the price of energy from fossil fuel plants. Both off-shore wind power and hydroelectricity depend on turbines and electricity transmission lines to consumer load centers. Both wind over ocean waves and flowing water in hilly terrain are at the mercy of the weather. Therefore it is not obvious if wind or flowing water will be preferred in the long run.

An interesting small hydropower facility is due to be installed in Massachusetts early in 2011. This was reported in *The Boston Globe* of January 3, 2011 under the headline "Getting a Power Boost from ordinary H_2O." The owner of the plant will be the Massachusetts Water Resource Authority.

This plant involves a water flow of 2000 million gallons per day over a distance of approximately 25 miles, from Wachusett Reservoir to the town of Weston, Massachusetts, embracing a water head (drop) of 194 feet. Calculations show that the gravitational energy consumption comes to 5,080 kW. It is believed that most of the gravitational energy is dissipated by uncertain flow losses, which include the passage through a water treatment facility. The remainder may be sufficient to supply the electricity needs for 110 average-sized households. Hence the economy of this small hydroelectric project is dominated by friction losses in duct flow.

The flow loss not only depends on the smoothness of duct surfaces, but also on the chemical nature of duct materials. Water is attracted by most solid substances. This attraction produces drag forces which apply tension to the intermolecular bonds in the water. The boundary layer drag is velocity dependent. With increasing flow velocity there comes a point when the intermolecular (hydrogen) bonds break and set the stored bond energy free. This diminishes the drag forces and has the appearance of negative friction. Therefore under certain condition the flow loss may be less than under other conditions. Since the effects of stored hydrogen bond energy are usually ignored in water science, there is much to be learned about this subject.

It is not stated in the *Globe* article what has been assumed to be the electricity consumption per household. This should almost certainly be less than an average of 10 kW. Then for 110 homes the turbo-generator output is expected to be less than 1,100 kW or just over 20% of the expended gravitational power. This is surprisingly low and may be the result of overestimating the flow loss. I am sure readers of *Infinite Energy* will be interested to see the performance figures when they become available later in 2011.

The large loss of energy due to water flow in long duct lines comes as a surprise. In cases where it is actually as high as 80% of the driving energy, it discourages the installation of low head hydropower systems. For a given low head, the most steeply dropping line will be the shortest line and, therefore, the most efficient installation. Maximum efficiency would be obtained with a waterfall.

The overall performance is also a function of the turbine efficiency. Experience has proved that the Francis turbine, with respect to efficiency, is better than all other water turbines. This is the turbine that has been chosen for the Wachusett-Weston project. The turbine efficiency depends on turbine size. With very large machines, in excess of 200 MW capacity, turbine efficiencies of over 95% have been reported. For the Wachusett-Weston turbine of 1 MW, the efficiency may not be much better than 50%. Allowing for this reduced small-turbine performance, the flow loss would still have to be one-third of the available gravitational energy.

Attractive sites for new hydropower plants of modest size are existing dams with water reservoirs which were built along rivers for flood control and agricultural irrigation. Today there exist 80,000 such dams with reservoirs in the U.S. Only 240, or 3%, are provided with hydroelectric generators. The dams and reservoirs were built at a time when the carbon dioxide-free generation of electricity was not appreciated. No financial help was offered by the government for renewable energy sources combined with flood control and irrigation. The only incentive for investments in hydropower was low electricity cost attainable with very large generating capacity like, for example, the Hoover Dam.

The power capacity of existing dams may vary up to 200 MW. This can be handled by a single turbo-generator and should be sufficient for a community of 20,000 single-family homes or equivalent industrial settlements. There must be provided an interconnection with the national electricity grid so that power can be supplied from other sources when the water flow is needed for flood control or similar purposes.

As far as the interconnection with the national grid is concerned, this will generally require a transmission line from the generator to the nearest point on the grid. The cost of the line will have to be charged to the owner of the generator. It is thought that in most instances the interconnection will not be longer than 50 miles.

Early in the 21st century, the Federal Energy Regulatory Commission estimated that flood control and irrigation dams, when fully equipped with hydroelectric generators, could add 60,000 MW to the electric power supply of the U.S. This was at a time when all the hydroelectric generators in the country furnished a total of 75,000 MW to the national electricity grid. It is equal to the output of 70 large nuclear power plants and represents far more clean energy than provided by all the other renewable electricity sources.

Hydropower is renewable because it relies on the solar evaporation of water from the oceans and, to a lesser extent, from inland lakes and rivers. Furthermore, solar heat lifts the water vapor to cloud level. It is this solar lifting process which stores gravitational energy in the fog of the clouds. In falling on mountains, rain and snow expend some of the gravitational energy. The remainder is stored in the water of elevated reservoirs. Since the cycle of evaporation, thermal lift to the clouds, and the collection of rain water in reservoirs can be repeated many times over, hydroelectricity is renewable energy.

Of the renewable energy sources that will be commissioned in 2011, wind turbines will probably be the most popular choice. This is surprising in view of the fact that the cost of wind energy, per kilowatt of electricity, is approximately twice that of fossil fuel electricity. By far the most economical way of generating electricity is by hydroelectric means, at about half the cost of fossil fuel sources. The financial advantage of hydropower cannot be ignored much longer.

Finally, it has to be pointed out that hydroelectric water turbines have the potential of adding liberated internal water energy to the gravitational energy of water which is processed by the turbine. The first discussion of this subject was published three years ago in *Infinite Energy* #78, under the heading "Upgrading Hydroelectric Water Turbines." The final paragraph of this paper states: "The existence of mechanically driven water heaters virtually proves that rotating machinery, breaking up water, does release stored hydrogen bond energy. If no special precautions are taken, the liberated bond energy will degrade to heat. Experiments with a spider turbine revealed, however, that fog droplets consisting of liquid water can be accelerated, presumably by chemical energy, within the turbine in such a way that the energy is added to the gravitational energy and then helps to drive the turbine and generate more electricity. A realistic research target would be to double the electricity output with an appropriately upgraded dual purpose hydroelectric turbine."

A more advanced treatment of "Boosting the Output of Hydroelectric Generators" will be found in *IE* #94. It strengthens the scientific, technological and economic basis of the process of combining gravitational and chemical bonding energy in a single machine.

A strong incentive for building more small hydropower plants is the fact that it will provide opportunities to experiment with dual purpose turbine designs and open the door to a new source of clean energy. We know that the unusually high efficiencies of water turbines have been obtained with the largest machines and not with small laboratory models. Therefore the development and testing of turbo-generators which capture hydrogen bond energy may have to be carried out in the field near a dam with a water reservoir. The largest existing water turbines have power ratings from 100 to 300 MW. Let us assume that the installation of more small hydro-plants cover machines up to 100 MW. Noticeable amounts of liberated hydrogen bond energy may become available at 1 MW. It seems reasonable, therefore, that a small hydro-plant program could cover the developmental testing of 1 to 100 MW turbine sizes.

Of course the foregoing argument, that small scale laboratory turbine models do not liberate hydrogen bond energy, may be incorrect. In that case turbine runners of the order of 10 cm diameter should be investigated. If experimenters can show that really small water turbines do liberate hydrogen bond energy, it would be a major advance in water energy technology. What has not been tried, as far as I know, is a small and very light turbo-generator driven with domestic water flow via a volume control valve. Some method of monitoring the momentum or energy flow is desirable.

Any turbine configuration could be used to start with. A convenient runner diameter is 6 cm. The induced voltage and load current should be measured on a sensitive oscilloscope. When this light machine is turning slowly, say at 60 rpm, the energy output should be steady. As the flow control valve is slowly opened and the flow past the turbine blades becomes more turbulent, the induced voltage and current amplitudes should increase. If a ripple or spike or a non-linear increase of energy is observed, this would be an indication of hydrogen bond energy liberation. All such observations should be repeated, recorded and published.

Environmental concerns and rising fuel costs will inevitably require that hydroelectricity at all scales will have to be seriously considered in the near future. Learning more about the mechanisms of liberating hydrogen bond energy in water turbines will further enhance the benefits of this vital renewable energy resource.