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ULTRA HEADLESS HYDRO POWER*

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EXTENDED ABSTRACT

Earlier this year the USDOE, through its Idaho Operations Office, solicited proposals for innovative, economical, low head hydro power plant idea development. For this purpose, low head was defined as 3m or less. Early hydro power projects were small scale and very close to load centers. Inefficient paddlewheels turned shafts in mills which, through belts, drove mill equipment. With the advent of electrical power, hydro power projects could be reasonably remote from load centers and located at optimum sites of high head and intermediate flow or high flow and intermediate head. The best sites were quickly exploited and secondary sites became uneconomical.

Secondary sites or those even more remote from load centers were then exploited by public agencies and the economics justified by power generation plus flood control and/or irrigation plus establishment of potable water reservoirs, to serve rapidly growing urban centers. Many of the earlier dams no longer were used to generate power as the mill-races vanished. Many new low head dams were used for flood control and evening flows toward hydro power projects, and were not furnished with generators since these sites were even more remote from load centers. Also, such low head dams could not compete with modern, efficient steam-electric plants firing fuel costing less than $2 per barrel of oil. The rekindling of interest in low-head hydro power is a natural result of the skyrocketing costs of fossil and fissionable fuel, since hydro power of any capacity is derived from a free energy source. This revived interest is still chained to electrical concepts of the recent past such as 60 Hz generators.

In general, low head hydro power runners have a low rotary speed requiring many tens of wound poles and closely governed speed control which makes such equipment cumbersome and expensive. Prior to high cost fuels, numerous studies were made of tidal power projects as at Passamaquoddy, Maine. All of these were considered "no go" by a plurality of experts due to the expected high cost of very low head turbine-generators and breakwaters which would have created a head commensurate with the 3m or less referred to above. Low head hydro power turbine-generators have been used to harness tidal energy in France and to replace very inefficient original equipment using tube turbines which can be inserted into many existing penstock-tailrace arrangements. All of these efforts, while expanding generating capacity, do not approximate the potential benefits of ultra headless hydro power. The limit of an ultra headless state is zero head which is impractical because when head is zero there is no flow. The ultimate attainment of hydro power from least head requires that flows be very large and heads be the velocity head that creates the flow velocity.

This leads to a necessary digression. How do we store electrical energy? There are many ways, most of which are impractical or very expensive. One very practical way is to use electricity to dissociate water into its

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constituent gasses, hydrogen and oxygen. These can be stored under high pressure, chilled to cryogenic temperatures to reduce bulk or, in the case of hydrogen, transformed temporarily into hydrides of small bulk but no pressure.

The fuel value of electrolytic hydrogen is equal to the electrical energy used in low temperature cell banks. If the initial energy source is free (hydro, geothermal or solar, for instance), the hydrogen and oxygen gasses can be stored for shipment and be recombined later to release the stored chemical energy. Hydrogen gas can also be combined with nitrogen gas to form liquid ammonia or gaseous carbon monoxide to form liquid methanol to simplify shipment and end-use. As a fuel, hydrogen contains three times the fuel value per kg of petroleum fuels and four to five times that of coal. Hydrogen burns to water vapor in the presence of oxygen, and as a gas is less dangerous than most contemporary gaseous and liquid fuels. It is very fluffy and, if leaked, will rapidly rise to buoyancy equilibrium at an altitude of about 20km.

If the electrolytically pure oxygen is also saved and recombined with gaseous hydrogen, this firing can take place in the most efficient and least costly of fuel cells having no fuel preparation section, boilerless steam turbines, and compressorless gas turbines. In each case, some of the effluent steam and/or water would be recycled to maintain temperatures within hydrogen age power equipment just under the maximum levels which can be tolerated.

The use of electrolytic hydrogen to store power releases the generation of electricity from the need for 60 Hz or constant generator rotor RPM. The exciter can be shaft-mounted and arranged to generate alternating current which can be changed to direct current using a solid-state shaft-mounted rectifier for use in the main rotor field current windings which will be rotated at varying speeds dependent on water velocity. The stator coils will generate alternating current power of varying frequency, voltage and amperage. Output power will be converted to constant voltage, direct current electricity of varying amperate using a solid state rectifier. The electrolytic cell-banks will then produce hydrogen and oxygen in direct relation to the direct current throughput at a rate of 28.3 m^3 of hydrogen gas per 63,000 ampere-hours.

The hydro power runners to accomplish the above generation can be of optimum design to derive power from large flows of fast currents of water. These could be of conventional design if used to capture the vast hydropower resources of Greenland which have many high head water run-offs on the ice-free east and west coasts /1/. To derive energy from fast-flowing rivers, swift-flowing ocean currents or tidal eagres having ultra low head requires water wheels of novel design akin to windmills.

Windmill wheels can be the multi-vane type where tip speed equals wind speed and blade coverage of the wind throughput path is fairly complete, or the airplane propeller type where tip speed exceeds wind speed by a factor of six or seven and blade coverage is fairly incomplete. Early versions were short radius multi-vane wheels used to pump water on farms and long radius one, two or three-bladed propellers shaped in accordance with aerodynamic principles used to generate electricity on a small scale. Other designs are less efficient and of less interest.

The efficiency of the multi-vane type wheel is about 30% while the best of the airplane propeller types is close to 47%. The possibility of using a hybrid type was discussed in an earlier paper /2/. This would call for an egg-crate construction to provide structural strength at higher tip speeds, and to contain multiple rows of blading with each row preset to achieve a good attack angle. Water flow velocity through blading could be increased at minimum hydraulic drag using fore cones and after cones to form a Venturi section.

A recent article on propellers noted that the principles of design of the propellers used to drive the superliner Queen Elizabeth II and the Gossamer Albatross were the same despite the tremendous difference in weight, area coverage and appearance /3/. This article went on to elaborate on current investigations which could result in propellers with many gull-wing-shaped blades having 70% area coverage being used to pull airplanes through the air at 80% of the fuel expended by fan-jet power plants at the same speed.

The use of these principles could lead to watermill wheels of immense size. These would have to be prefabricated in sections sized to allow shipment to the power plant site. There they could be welded together or equal to form wheels of very large diameters. When used with fore cones and after cones having two times wheel diameter, water velocity is increased by four and power output is 64. Fore and after cones can be stiffened by stranded stainless steel cables stretched from flange to flange. The fore cone inlets should be screened to prevent entry of heavy logs, mammals and large fish.

The optimum arrangement would have stators with a diameter somewhat larger than the wheels, and main generator rotors with a diameter slightly larger than the wheels. This would make lines of force-cutting speed equal to tip speed and optimize the use of a rigid structure needed between two wheels (or more) on the same shaft. By large wheel diameter, tens of meters is meant. Such wheels could generate over a 1,000 MW per pair, be suspended from barges anchored in the gulf stream, for instance, with hydrogen gas production cells mounted on the barges.

What is true of watermills is applicable to windmills. Unfortunately, air has a density less massive than water by a factor of 832 at standard conditions, and windmill outputs will be correspondingly lower. Watermill wheels could also be located on land in white water rivers and in tidal eagres. Here the wheel diameters would be necessarily less and power output per unit correspondingly lower. Nonetheless, since head loss per unit is very low, and the number of units is not particularly limited, such plants could well be a useful adjunct to our overall generating capacity.

The watermills (or windmills) described above would have to be designed to withstand maximum fluid velocities, and this would produce electricity at increased rates when such fluid velocities occur. This is not true of recent windmills which must turn tail and flutter when winds of 100 Km/Hr arise. Likewise, hydrogen production cell-banks—cannot be overloaded, although production efficiency will drop when ultra low head currents are ultra swift.

REFERENCES

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