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MHD conversion and nuclear systems

by Marsha Freeman

Magnetohydrodynamics is the technology of direct energy conversion that applies the physical principle that if an ionized fluid is passed across the lines of force of a magnetic field, an electric current is produced. Most international attention has been given to MHD conversion in fossil-fuel-based systems and these designs today have the most immediate large-scale potential for producing power for a power grid.

But MHD conversion can also be achieved in nuclear systems. There are two main approaches aimed at getting around the problem that conventional nuclear fission plants and advanced breeder and high temperature plant designs and processes do not produce a "combustion" product made up of charged particles and, therefore, the neutron heat from the reaction must be transferred to a working field that can be easily ionized.

One approach is to use a noble gas (argon or helium, for example) ionized by the high temperature neutron heat as the working fluid in a closed-cycle arrangement. Until the mid-1970s, this approach was still considered most appropriate for linkage with a high-temperature heat supply, with a projected working fluid of helium or argon seeded with cesium. Efficiencies of 50 to 54 percent were calculated with a 2,000 degree Kelvin inlet temperature.

Although the commercial development of the high-temperature gas-cooled reactor has been written off by the Carter administration, studies are continuing, particularly in the Netherlands and in Japan for noble gas plasma systems with nuclear power. The Japanese design utilizes a disk-shaped geometry and argon plasma which has a single load rather than dozens of separately connected electrode pairs.

Another approach is the use of a mix of a gas working fluid and liquid metals. The major U.S. work on liquid metal MHD, known as LMMHD, has been at Argonne National Laboratory in Illinois, concentrating on the development of the intricate MHD generator. Experiments at Argonne began in 1972 and small experimental devices are in operation.

The main difficulty in using a liquid metal for MHD is that it is basically noncompressible and therefore cannot be accelerated appreciably through the MHD channel by itself. To solve that problem researchers have devised various two-staged systems.

The major advantage in LMMHD is that the liquid metal is a highly conductive fluid and therefore very large electrical currents are expected. Also, the use of liquid metals in fast breeder reactors and in fusion reactors avoids the liquid metal-to-water-interface of a steam turbine power generating system.

Power conversion from a liquid metal system can be attained at considerably lower temperatures than those needed with the noble gas plasma designs. Experiments at Argonne on devices approximating the design parameters of a commercial system have been in the range of 400 to 1,000 degrees Fahrenheit. Commercial systems using the heat from breeders would go as high as 1,360 degrees Kelvin.

In a basic LMMHD design, the inert gas is the primary working fluid, which expands through the nozzle into the MHD channel, driving the liquid metal mixed with it across the superconducting magnetic field. The liquid metal, the electromagnetic fluid, has a high heat content and the expansion occurs at near-constant temperatures so that the liquid metal acts as an "infinite reheat" for the gas.

Much of the heat remaining in the gas after the MHD conversion can be recaptured after it is separated from the liquid, recouped in a regenerative (direct) heat exchanger, and fed back into the gas and liquid mixer. The heat could also be used in a steam or gas turbine bottoming cycle.

For the next generations of nuclear MHD systems, there are several designs being proposed. One design put forward utilizes the advantages of inductive compared to conductive MHD conversion.

An induced current is produced when the interaction of the gas or conductor and the external magnetic field are nonstationary: either the flow is subjected to an oscillating magnetic field or the steady magnetic flux is "pushed" by an oscillating or pulsating gas flow. A potential difference is created at either end of the conductor by the oscillations from the changes in motion of the field of flow. If the flow is pulsed, the induced current can be drawn off from the magnet and directly put into the alternating current grid system without first going through an inverter system.

Nuclear MHD systems hold great promise for direct energy conversion—if the United States restores its commitment to nuclear power developments.