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MHD makes fossil fuels efficient

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Taking coal, partially ionizing it in the process of burning it at high temperatures, and passing this ionized fluid across the lines of force of a magnetic field will produce an electrical current. This is the area in development of magnetohydrodynamic technologies that has received the most attention and has the most immediate large-scale potential.

Compared to conventional steam turbine cycles, MHD requires higher temperatures and, at higher temperatures, more electric power can be extracted from the fuel. MHD combustion temperatures range from 4,000 to 5,000 degrees Fahrenheit; the upper limit for steam generators is about 1,800 degrees because of material constraints and the stress of rotating huge pieces of machinery. The exit gas from an MHD generator drops about 2,000 degrees from the inlet temperature, creating a larger temperature differential and therefore a more efficient conversion system. The exit gas is also at low enough temperatures to allow its transfer into a steam turbine cycle.

In terms of fuel consumption, first generation MHD coal fired plants are expected to achieve a cycle efficiency of 48 to 52 percent (compared to steam cycle efficiency of 35 to 40). Second generation plants are expected to convert up to 70 percent of the thermal energy in the combusted coal to electric power. Put another way, the MHD conversion system would extract twice or more electric power from each unit of fuel than present technology. Therefore, although some of the components of an MHD system would be more expensive than off-the-shelf steam turbines, the fuel cost would be about half. A 1978 projection has placed the cost of delivered power from an MHD system near 32 mills per kilowatt-hour compared to 45 mills for a conventional plant with the same capacity.

Another factor that would lower the cost of MHD generated electric power is the fact that MHD is an environmentally excellent system. Combustion is complete, reducing particulate emissions from the system by more than 90 percent. Potassium used in the combustion process to increase electrical conductivity chemically bonds with the sulfur in the coal, reducing sulfur dioxide emissions by 99 percent and eliminating the need for costly stack gas scrubbers. It has been found that the sharp 2,000 degree drop in temperature from the inlet to the outlet of the MHD channel decomposes nitrogen oxides, another polluting emission. MHD systems can also greatly reduce the heat a power system releases into the atmosphere by, for example, directing the exit gas into a steam cycle.

The basic open cycle coal-fired MHD generator system that uses exhaust heat for the steam turbine bottoming cycle has three major systems: the fuel combustion unit, the MHD generator and the bottoming cycle. The last is already operating technology; the challenge in the MHD system has been designing new components for the generator.

Briefly, design and experimentation is ongoing in the following:

- Electrode designs to maximize power output from the complex interaction of the magnetic field and electrical field configurations in the MHD channel. Here the problem is to mitigate the effects of the electrical field that is generated when the current-carrying MHD fluid is placed in a magnetic field so that the electrodes which draw off the current are not shorted out. Another problem is to develop electrodes that can withstand both the temperature and corrosive environment of the hot coal gas. Work on electrode development is ongoing at General Electric, Reynolds Metals, Westinghouse, the Massachusetts Institute of Technology and Avco.
- Combustion temperatures. This is the major determinant of the electrical conductivity of the gaseous working fluid. This temperature can be increased by preheating the air used in combustion. There are three methods: independent burning of a clear fuel to provide heat; direct use of MHD exhaust gas recycled back into the combustion chamber; or use of the MHD hot exit gas through a heat exchanger system.
- Magnetic field strength. Conventional water-cooled magnet systems cannot exceed field strengths of more than about 3 tesla or 30,000 gauss. A baseload MHD power plant will require magnets in the range of 5 to 7 tesla. To provide such field strengths without the magnet needing more power than the plant produces will require superconducting magnets—like the one used on the ETL Mark V MHD generator in Japan. Development and fabrication of these magnets is ongoing at Argonne National Laboratory, General Electric, MIT, and Stanford University.

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