Energy 111: Magneto Hydrodynamics and Total Energy Systems

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Don’t let the title scare you into excluding this from your reading schedule. An attempt will be made to simplify the concept and its uses. Let’s start by calling them MHD and TES respectively for short. Many practical applications of TES were evolved from its age-old principles over a half century ago, during the “Total Energy” movement, which was started to cope with what appears in retrospect to have been a contrived energy shortage. This movement was centered around attempts to utilize the waste (‘Unavailable’) energy, i.e. energy that would ordinarily be discarded by electric power plants according to the dictates of the Laws of Thermodynamics (energy utilization laws). Discharge of waste heat from these plants in the form of hot gases from the combustion of fossil fuels and ‘cooling’ water from the steam turbine exhaust steam ‘condenser’, where the gaseous water vapor is condensed into hot liquid water to be returned as ‘feed-water’ to the steam boiler to be converted again into steam.

More than a century ago, many large extreme northern and southern latitude cities throughout the World recognized a viable use of that “dead” steam, while at the same time reducing the pollution from the many coal burning heating furnaces in the business places concentrated in the inner cities. In conjunction with the electric power companies, they passed laws and signed agreements to place power plants near the business centers of the cities and forced the business places to buy heating steam (steam turbine/engine exhaust) from the power plants. Many large northern cities still use the approach of having a labyrinth of steam lines in utility tunnels throughout their business districts . . . that the buildings can tap into. The steam is used for heating and also for snow/ice melting by building pipes into the sidewalk and drive pavements. After being condensed and the condensate cooled to warm liquid, it is passed thru a meter and dumped into the sewer and the individual businesses pay their heating bill to the electric power company, based on those readings. In some cases, there may be a cost savings and a ‘green act’ to pipe this condensate back to the power plant and re-use it as boiler water.

Certain industries in remote areas that have a need for large quantities of hot air to dry or age their product (lumber mills, paper product plants, etc.) find it more

economical to generate their own electricity using gas turbine or diesel engine powered generators . . . and use the hot exhaust gases for that purpose.

One of my consulting jobs in the 1960s era was to prepare a data collection/analysis plan as well as specify the type and location in the system, of the instrumentation necessary to evaluate the cost benefits of the Total Energy System (TES) that was being used in a service center, in the City of Milwaukee, by the Wisconsin Gas Company, who supplied natural gas to a large portion of the state. The facility occupied the better part of a city block and housed billing offices, customer service operations, a meter repair/calibration facility . . . as well as storage and repair facility for all their service trucks, trenchers, and other equipment. The utility services to the facility were gas, water, and sewer lines. They did have electric grid power lines available for emergency purposes.

That TES consisted of three 900 HP Diesel piston engines running on natural gas enriched with diesel fuel. Each engine drove a separate 220VAC, 3 phase electric generator, with transformers to provide electric power for the entire complex. The entire load could be easily handled by two units with the third serving as an emergency standby. The engines were alternated so as to keep about the same operating hours on each. The hot gas exhausts from the engines were fed to three ‘waste heat’ boilers (augmented by natural gas burners), generating low pressure steam that was piped throughout the complex for comfort heating during the winter months. Summer cooling of the complex was provided by a chilled water system supplied from an ‘absorption’ refrigeration unit (called Planten-Munters or Servel refrigeration) powered by steam from the waste heat boilers.

So, what is MHD and how does it fit into the TES picture. Actually the term Magneto Hydro Dynamics is only one of several names applied to the phenomenon, depending on the interested physical science area. Some of these alternate names are: cosmical electrodynamics, plasma physics, plasma dynamics, magneto-aerodynamics, magneto-fluid-dynamics, etc. The MHD terminology is probably the most common in the electrical power generation area. The basic working principle is: passing an ionized (by high temperature or ‘seeding’) fluid (liquid or gas) at high velocity (by means of a convergent-divergent nozzle), between the poles of a magnetic field, induces an electrical potential (voltage) between metal plates placed at right angles to the magnetic field and parallel to the velocity vector of the fluid. In other words, it is an electrical generator with no moving parts. It is, of course, a direct current (DC) generator and for common use, must be converted to alternating current (AC) by an inverter.

Since significant ionization of a gas can only be achieved at a very high temperature, there must be an external heating process of the working substance, such as a solar collector, nuclear reactor, gas turbine, jet engine, or other fossil fuel burner, before entering the MHD generator. Leaving the MHD generator after the electrical energy generation, the working substance is still fairly hot and possibly contaminated (if a toxic substance was used for ‘seeding’ the ionization process). Simply discarding the high temperature working substance would be wasteful of the energy it still contains . . . and that is where the Total Energy concept is applied. This high energy exhaust working substance can be used as a heat source in a

conventional steam boiler/turbine/generator system, thus achieving an overall higher efficiency of energy conversion for the combination. Economic analysis has shown this Total Energy approach can yield approximately a 10% reduction in the cost of the produced energy, over a conventional fossil fuel steam power plant. If you are interested in an excellent detailed treatise on MHD (as well as all the topics in this Energy series), it may be found in the book Direct Energy Conversion, by Stanley W. Angrist, 1965. (Not suggested for the faint of Math and Physics.)

Early in the game, as with all the non-mechanical schemes, it was hoped the “direct” MHD approach to electrical power production from thermal energy would bypass the Second Law of Thermodynamics (more than 60% of the input energy must be discarded as “Unavailable” to do useful work), but alas, Mother Nature won again.

Somewhere back in the early 20th Century, it was discovered that if an MHD generator were ‘reversed’ (an external electric potential being applied to the plates), it could become a ‘pump’ for high temperature liquid metals. And if designed to pump seawater, which is easily ionized at low temperature, it could be used as very quiet, non-propeller propulsion for ships and submarines (ala the Soviet super-sub in “The Hunt for Red October”. . . book by Tom Clancy and a Hollywood movie).

The preceding is the opinion of the author and not that of ECN.

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