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The Gauss Fusion (GFG) GIGA Magnet System

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***Abstract*–The GFG Fusion Power Plant is based on a stellarator with a four period quasi isodynamic plasma which, supported by results from Wendelstein 7X and advances in plasma modelling and stellarator optimisation, is expected to achieve the required confinement levels. It is sized to provide output electrical power comparable to a conventional large power plant, with realistic assumptions about power generation, auxiliary heating system efficiencies and nuclear component lifetimes: 1GW electrical from 3GW thermal, with a neutron wall load on the first wall of under 1MW/m2. This provides a major radius of 18m and a minor plasma radius of 1.7m, with a field on axis of 6T and a maximum field on the coils of 12-13T.**

The stellarator configuration is particularly suitable for a fusion power reactor. It is steady state, the high aspect ratio provides easy access all around the plasma and the lack of a net plasma current (and the associated vertical stability and disruption issues acting as design drivers in tokamaks) greatly simplify the magnet and vacuum vessel designs. The steady-state nature reduces cyclic stresses on all components, including the magnets. Stellarators are well known as requiring many non-planar magnets which are often seen as design and manufacturing problems as well as generally obstructing access to the plasma. GFG is focused on a baseline design and developing magnet technology that enhance the operability of the plant and solves these disadvantages.

The medium field levels of GIGA allow both LTS and HTS superconductors to be potentially applicable and GFG is developing both with a common cross-section (circular with a diameter of about 55mm) and current (100kA) but different operating temperatures that can be used interchangeably in a common magnet design. The magnet technical development is directed on structural optimisation, protection in the event of quench, magnet repairability and improved access to the internal nuclear power producing components.

The GIGA magnet system consists of 40 coils, with 5 different shapes each replicated 8 times due to the symmetries. Each coil is non-planar with an approximate perimeter of 30-35m (a major diameter of 10m). The coils are therefore similar in size, field and capacity to those of the ITER TF system and will also weigh about 300t. So apart from the 3D shape, manufacture of the GFG coil system is roughly equivalent to two sets of ITER TF magnets. Such a set of magnets is large but would be well within the capacity of the production lines established for ITER, and can be transported from manufacturing site to power plant site in similar ways.

The magnets use a conductor-in-plate concept and curvature constraints are imposed on the shapes of the magnets so they can be bult up from cylindrical shells or flat plates curved in circular arcs. This enables the plates to be stacked to form a coil, with the distributed structure avoiding the use of a case and all the associated fitting problems. The use of plates also supports the GFG demountable coil concept which is a key technology to offer improved options for manufacturing, assembly, repair and regular operational maintenance. The coils can be mounted and demounted in handleable units (less than 20t) and an in-line joint system (mechanical and electrical) is compatible with remote handling and is space efficient. A single coil needs to include some 250 joints so a low resistance target of about 1nOhm has been set which is regularly achieved with LTS joints and would be acceptable as a cryogenic heat load. Continuing to exploit features of the conductor in plate concept, GFG is developing a low voltage quench protection system which is seen as critical to avoid the inherent high voltage incompatibility with cryogenic vacuum problems that are familiar from superconducting tokamaks that rely on external resistors to extract the magnetic energy.
The paper will describe the GFG conceptual design of the magnet system and status of associated development programs.

***Keywords (Index Terms)*– Stellarator, Fusion, Magnet Design, Quench, HTS Cable, LTS Cable**

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