Performance History and Upgrades for the DIII-D Gyrotron Complex

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The gyrotron system on the DIII-D tokamak presently comprises 6 operating tubes, with infrastructure for 8, all of which nominally generate 1 MW for short pulses and ≈800 kW for operational pulse lengths, which are limited administratively to 5 s, consistent with the DIII-D pulse length. All of the gyrotrons operate at 110 GHz. Two are a depressed collector design, part of a recent upgrade, while the others are older undepressed diode tubes. As funding permits, the installation is transitioning to a new series of gyrotrons with a higher frequency of 117.5 GHz, the first example of which has demonstrated 1.8 MW 5 ms pulse operation at 60 A and 1.5 MW at 50 A in initial testing. Two gyrotrons are undergoing repair and will be returned to service. One developed an internal water leak and a second failed due to a problem with the electron gun. Both of these failed tubes had been in service for about 10 years. Maximum injected rf power has been about 3.4 MW and this performance level is expected to continue to be realized during the 2014 experimental campaign.

The gyrotron system on DIII-D began operation with 1 MW class tubes in 1997 and since then has been steadily increased in capability. The overall reliability for successfully meeting a performance request has been about 85% even though four gyrotrons are operated in pairs on single power supplies, hence a fault in one causes two to be lost for the shot.

There are four dual launcher assemblies on DIII-D, each of which can handle full power from two of the gyrotrons, with individual waveguides and fully articulating steering mirror assemblies. Using these steering mirrors, the rf beams can be directed over a 40° range in the vertical, poloidal, plane and ±20° horizontally, giving access to the plasma center and above, while providing current drive in either direction. This steering capability is being upgraded with higher speed drive motors and new position readback encoders, which have demonstrated a full 40° poloidal scan in <200 ms and about 2 mm position accuracy for the rf beam at the plasma center in initial tests. The aiming and appropriate polarizer angles can be set up and fixed prior to a plasma shot with preprogrammed time dependence of the rf power, but aiming and output control can also be assumed by the DIII-D Plasma Control System (PCS). Under PCS control, real time equilibrium calculations guide the aiming. Feedback control, based on diagnostic input, provides the basis for determining the required heating or current drive and the result is the ability to fully suppress MHD instabilities such as the neoclassical tearing mode, to influence the j(r) and $T_e(r)$ profiles and study transport and other fundamental aspects of the discharge.

In addition to the more familiar plasma physics and fusion related experiments, the ECH system is also being used in an experiment in conjunction with NASA as the power source for small rockets being accelerated by microwave heating of fuel without use of an oxidizer. Tests of the design of suitable heat exchangers and engines are ongoing.

The long-term upgrade plan for the DIII-D gyrotron complex calls for 10 gyrotrons with a regular replacement program leading to most or all of the tubes at 117.5 GHz with nominal generated power of 1.5 MW per unit. This will require upgrades to the building, new high voltage power supplies, one additional dual launcher, and controls to expand beyond the present 8 gyrotron system.

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