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AGS BOOSTER PROTECTIVE DEVICES

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AGS Booster Protective Devices

A. From an electrical systems point of view the AGS Booster Accelerator is a magnet load, powered by a 24 pulse AC to DC thyristor controlled power supply (BMMPS). The BMMPS is comprised of six, twenty-four pulse modules and twenty-four rectifier transformers. The magnet is a fixed resistive / inductive load of 0.1 Ohms and 0.15 Henries. During the acceleration portion of the cycle energy is taken from the line and stored in the load inductance. This process can be modeled as a voltage source applying a step voltage to a highly inductive load. When the voltage step is applied, the current in the magnet inductance rises essentially in a straight-line, linear fashion. Later in the cycle, when the current reaches the desired value, the stored energy is returned to the line minus the system losses, by inverting the imposed voltage. The Booster typically operates in this way for a burst of three to seven pulses every four seconds.

B. The BMMPS is well protected. Interlocks assure that if a malfunction occurs, or if operations occur in a wrong part of the current / power / frequency space, the Booster circuit breakers will be tripped. This protection is independent of the PPMR operation. The incoming AC lines are protected with instantaneous and timed overcurrect relays as well as ground fault protection. Each of the six rectifier modules has its own circuit breaker. These six circuit breakers are fed through a common seventh circuit breaker. The DC side of the system is protected with over current and over voltage trips, ripple detection interlocks, ground fault interlocks and circuitry which detects improper thyristor firing. These protective devices are adjusted to quickly take the power supply off line if the output significantly deviates from the programmed function.

C. The DC output of the power supply is constantly monitored by a computer-based system which records the instantaneous output current and voltage of the power supply and computes the fast Fourier transform (FFT) of the load power every AGS supercycle (typically every 4.0 seconds). If the DC power spectrum exceeds programmed limits this equipment will initiate a system alarm. The power spectrum is inputted to the AGS closed circuit TV system and is visible in the MCR. This monitoring device essentially duplicates the function of the PPMR. Before new cycles are run they are inputted into this system and analyzed for unacceptable spectral components.

The following describes the "areas" of operation of the AGS Booster. It is not intended to be a complete review of the technical operations of the machine but is presented to give an overview of how it is set up to operate in its various modes:

1. The Booster operates as one of a group of five (5) accelerators that comprise the high-energy research facility at BNL. Each machine acts as a pre-amplifier, feeding particles at ever-increasing energies into the succeeding machines. The operation of each machine is extremely sensitive to changes in the parameters of the preceding machine. The maximum energy that the Booster can run at successfully, for example, is fixed by the maximum energy the AGS can accept. If the Booster power supply operating frequency or energy were to change unintentionally the beam could not be successfully transferred to the AGS and accelerated to the experimenters. This effectively limits the maximum power the BMMPS could draw from the utility for any practical experiment. The accelerated beam is the only product of the AGS and as such is constantly being monitored for intensity, ripple, and position by many different pieces of equipment and dozens of qualified scientists and engineers. Any change in the Booster repetition rate or energy would be immediately known.

2. The operating cycle for each machine is determined well in advance of machine turn on. The run schedule and operating cycles are determined by the AGS upper management and cannot be changed without approval. Typical runs are usually set for periods of from one to six months.

3. Only qualified operations personnel are allowed to make changes to the machine parameters. These personnel are fully trained in the "proper" scheduled machine operating parameters.

4. Once the "mode" of Booster operation is set (see 2 above), only a few (3 to 4) responsible Engineers and Physicists are permitted to generate the voltage and current waveforms that are used to drive the power supply.

5. Cycles at the permitted frequency ranges are not just "dialed-in" or run by "pushing a button". Waveform generation requires a complicated computer program, where the desired magnetic field shape is systematically entered one point at a time. This guarantees that the cycle begins and ends within the predetermined time (i.e. 200 msec for 5 Hz operation, 133.3 msec for 7.5 Hz operation, etc.) and that all generated waveforms are without singularities. The computer program includes checks at many points during this process. When waveform generation is successfully completed, the correct function is down loaded to

memory buffers at each of the six power supply modules. Information in these buffers is not sent as a reference command to the power supply until it is carefully checked (see 6).

6. Before any successfully downloaded function is run, it is tested. This consists of taking an FFT (using the system described in "C" above) of the stored voltage, current and calculated power waveforms, and viewing the input analog command to the power supply with an oscilloscope. Finally the Booster circuit breakers are closed and the power supply is put in a mode ("single-cycle mode") where it can output only one cycle of the desired waveform. The power supply output is studied and if acceptable the final operating cycle is allowed to run, usually in a "burst mode" (see "A" above).

7. The Booster operational cycles are widely displayed on the AGS closed-circuit TV system and at a glance the Main Control Room (MCR) Operators can determine when something is not as intended. The MCR is always "manned" when the Booster is operating.

In addition to the AGS and Booster accelerator there are other important loads at BNL, such as the National Synchrotron Light Source (NSLS), which depend on clean reliable power. The NSLS is much more susceptible to harmonic and voltage flicker problems than standard industrial or residential loads. Because of its sensitivity to power quality and its electrical proximity to the Booster, it is a major concern of the BNL engineering staff to minimize any line disturbances caused by the BMMPS. Any malfunction of the BMMPS would cause serious problems to the other loads on site and would be quickly detected. Users on site are very aware of the BMMPS signature. It is clearly in BNL's best interest to preserve the integrity of the power distribution system.