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Engineering Note

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Project: DZERO Solenoid Installation
Doc. No: H970123A

Subject: Solenoid Power Supply Circuit Breaker Calculation

The solenoid will require a maximum of 15 Volts @ 5000 Amps dc. The power supply which will be used is a PEI 150 kW unit. This power supply was previously used to operate the DZERO small angle muon system (SAMUS) toroid at 55 Volt @ 1000 Amps. This note compares the 480 Volt ac current requirements of the two applications to verify that the present circuit breaker (300 Amps) and conductor size (350 MCM) may be used for the solenoid application that was used for the SAMUS application.

- First we evaulate the original Installation for SAMUS:

1. The dc power (P_{dc})(Watts) required for 55 Volts (V) @ 1000 Amps (A):

$$P_{dc} = V \times I = 55V \times 1000A = 55,000W$$

2. The input power ac (P_{ac}) required for 55,000 Watts output power dc (P_{dc}) assuming a power supply efficiency (eff) of 93% full load (from mfg. specs):

$$P_{ac} = \frac{P_{dc}}{eff} = \frac{55,000}{0.93} \approx 59,100W$$

3. The ac Volt-Amps (VA) required to produce 59,100 Watts assuming a typical power factor (pf) of 0.7 for this large power supply (from previous run experience):

$$VA = \frac{Pac}{pf} = \frac{59,100W}{0.7} \approx 84,400VA$$

4. The average phase current (I_{ave}) Amps (A) required to deliver 84,400 VA at 480 Volts:

$$I_{ave} = \frac{VA}{480 \times \sqrt{3}} = \frac{84,400}{480 \times \sqrt{3}} \approx 102A$$

- Next we evaluate the new installation for the solenoid. Following the same procedure to determine the phase current required to deliver 15 Volts @ 5000 Amps gives us:

1. The dc power required for 15 Volts @ 5000 Amps:

$$P_{dc} = V \times I = 15V \times 5000A = 75,000W$$

2. The ac power required for 75,000 Watts assuming a power supply efficiency of 93%:

$$P_{ac} = \frac{P_{dc}}{eff} = \frac{75,000}{0.93} \approx 80,600W$$

3. The ac Volt-Amps required assuming a typical power factor of 0.7:

$$VA = \frac{Pac}{pf} = \frac{80,600W}{0.7} \approx 115,000VA$$

4. The average phase current required to deliver 115,000 VA at 480 Volts:

$$I_{ave} = \frac{VA}{480 \times \sqrt{3}} = \frac{115,000}{480 \times \sqrt{3}} \approx 138A$$

- Conclusion:

Clearly, the 300 Amp circuit breaker, which was used to supply an average current of approximately 102 Amps to the power supply for its previous SAMUS operation at 55 Volts and 1000 Amps; is adequate to supply approximately 138 Amps to the power supply for the solenoid operation at 15 Volts and 5000 Amps. The 350 MCM conductors, which are NEC rated at 350 Amps capacity, is also clearly adequate. Note that these conductors are doubled (two in parallel) for the long distance run from DAB north to DAB south across the pit.

We must also consider the impact of inrush currents. These currents, which occur at the instant the power supply contactor pulls in, are due to the initial magnetizing currents into the power supply's main power transformer. The currents could be considerable and must be supported by the circuit breaker when the supply is first turned on. The inrush currents should be the same for both configurations of the power supply due to identical tapping of the primary windings. Also, the new installation is about 100 feet further away from the circuit breaker than the old installation thus increasing the impedance to sudden current changes. Thus, inrush currents should not adversely affect the use of the original circuit breaker with the new installation.