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1000-kVA ARC POWER SUPPLY*

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Summary

Because of ever-increasing power demands for the development of the Oak Ridge duoPIGatron ion source, a continuous-duty arc power supply was constructed for the Medium Energy Test Facility (METF) to furnish power for the plasma generator of experimental ion sources. The power supply utilizes 12-pulse rectification with half-wave switching in a delta and wye full-wave bridge that may be connected in series or parallel. It will deliver 340 V dc, 2500 A to an ion source when series connected and 170 V dc, 5000 A when paralleled connected. Silicon-controlled rectifiers (SCR) in each rectifier bridge can be switched for pulses as short as 10 ms through continuous duty. The filter section that reduces the ripple in the output consists of an inductor-to-capacitor (L-C) filter to smooth the 720-Hz pulses. The power transformer serves as an isolation transformer allowing the secondary to be elevated to the accelerating potential of the ion source. The dc output level is controlled with a 1000-kVA auto transformer connected to the primary of the power transformer. All elevated voltages and currents are monitored at ground potential with an optical telemetry system.

This paper describes the power supply in detail, including block diagrams, component specifications, and waveforms when supplying power to an ion source.

Introduction

A 1000-kVA arc power supply was designed and constructed for the Oak Ridge National Laboratory, Fusion Energy Division's METF for developing high current ion sources. Although the Poloidal Divertor Experiment (PDX) 30-cm ion source presently under development requires only 1200 A of arc current, the supply is rated for much larger ion sources. It was designed for ion sources beyond PDX that will require arc currents up to or above 2500 A. All components of the system are rated continuous duty for long pulse or dc operation.

System Description

The arc power supply (Fig. 1) is made up of a circuit breaker, variable transformer, power/isolation transformer, rectifier assembly, and associated controls. The continuous-duty dc output is 340 V dc at 2500 A, or 170 V dc at 5000 A, or higher currents in the pulsed mode. A variable-voltage transformer (VVT) supplies a variable primary ac voltage to the combination isolation and power transformer for variable dc output voltage. The power transformer secondary and the rectifier assembly are isolated to 150 kV dc to supply arc power to the ion source, which is elevated to the accelerator potential. The output of the power supply is switched with SCR's in the rectifier assembly. The pulse and metering information at high potential is transmitted to the control panel with an optical telemetry system.

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Arc Circuit Breaker

The power supply is fed from a 600-V ac 3-ϕ, 2000-A air circuit breaker that serves as an on-off switch and also protects the supply from ac line-over-current. The breaker is opened and closed from the operator's control panel.

Variable-Voltage Transformer

The dc output of the power supply is controlled with a continuously variable autotransformer (Fig. 2) connected to the primary of the power transformer. The VVT consists of an isolation transformer and a commutating transformer cross-connected such that it offers a low impedance with good regulation throughout the control range of 0-100%. The commutating section is 12 vertical columns with a sliding brush assembly for the output variable voltage. The input of the transformer is 3 ϕ, 60 Hz, 480 V ac. The output is continuously variable 0-480 V ac, 3 ϕ, 60 Hz, capable of 1204 A. The maximum impedance at any output is 5.5%. The overall size is 72 in. wide, 120 in. long, 111 in. high, and it weighs 21,500 lb.

Transformer

The power transformer (Fig. 3) is contained in an oil-filled tank with radiators on each side for cooling. The input cables are feedthrough bushings mounted on the top cover along with spark arrestors to prevent transients from getting back into the 480-V ac feed. The secondary delta and wye connections are made through individual bushings on the top cover of the tank. The primary-to-secondary isolation is rated at 150 kV dc and tested to 300 kV dc. The primary and secondary of the power transformer are separated with a shield to reduce voltage transients and noise.

The transformer primary is a 480-V ac, 3-ϕ, delta-delta connected in parallel. The secondary is a 140-V ac line-to-line (L-L) and a 2062-A delta-wye, which are insulated from each other for 12-pulse rectification. The overall size is 92 in. wide, 100 in. long, and 116 in. high, and it weighs 21,000 lb.

Rectifier Assemblies

DC rectification is accomplished with two forced-air-cooled 3-ϕ rectifier assemblies (Fig. 4) that utilize half-wave switching for pulsing. Each assembly is isolated such that each can be connected in series for 340 V dc at 2500 A or in parallel for 170 V dc at 5000 A. An interphase transformer is used in the parallel model to help distribute the current from each section. An L-C filter in the output reduces the 720-Hz ripple and serves as a dc current limiter in the event of a short circuit in the ion source. The filter choke is rated at 300 uH at 5000 A. The cap bank is 4000 uF at 800 V, which reduces the arc gas discharge noise that is generated in the ion source.

Control System

All control functions are on a single operator panel (Fig. 5) that contains all logic and data signal circuits.

The secondary dc voltage and current are displayed with digital panel meters utilizing sample and hold circuits. A 33-ms sample is made on each pulse and is displayed until the next pulse occurs. The sample may be moved along the pulse to make the reading at any point during the pulse. An intensity control identifies where the sample is being made and is displayed on the oscilloscope waveform (Fig. 6). For continuous loads on the supply, the digital meters update every 100 ms for continuous reading. The voltage and current measurements that are made at high potential are transmitted to ground through an optical telemetry system.[1]

A position indicator on the control panel identifies where the commutators are on the variable autotransformer. The autotransformer must be at the zero position to energize the 2000-A air circuit breaker. This prevents turning on into unknown arc loads.

Several overload protection features are incorporated into the power supply. The 2000-A air circuit breaker has line overload current transformers (CT) that open the breaker when excessive line currents are sensed. Each secondary line of the power transformer is fused with time-delay fuses for secondary line faults. A variable dc overcurrent control on the operator panel can be set to limit the current to the ion source. When the preset limit is exceeded, the SCR's in the rectifier assemblies are turned off; when the current falls to a safe value, the SCR drive is restored and the pulse continues. An inhibit circuit is sometimes used to lock out the drive for the remainder of the pulse if the operator does not want to continue the pulse. The inhibit system can also be connected to other power supplies and functions of the ion source such as accel power supply, decel power supply, and anode 1-anode 2 current ratio. An overtime trip circuit can be controlled from the operating panel to limit the length of a pulse. In the event of some failure in the power supply such that it will not inhibit or turn off, the overtime circuit will open the 2000-A air circuit breaker after some present time. An external interlock can be connected to gates and doors and will turn off the power supply if interrupted.

The power supply has been in operation for 12 months and has given little or no problems. It is sized such that it will be capable of supplying arc power for all ion sources under present consideration.

Reference

1. R. E. Wright, Proc. 7th Symp. on Engineering Problems of Fusion Research, Vol. II, p 1579 (1977).

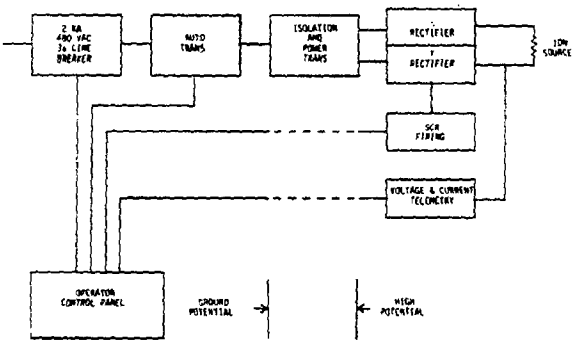

Fig. 1. 2.5 kA arc power supply Medium Energy Test Facility

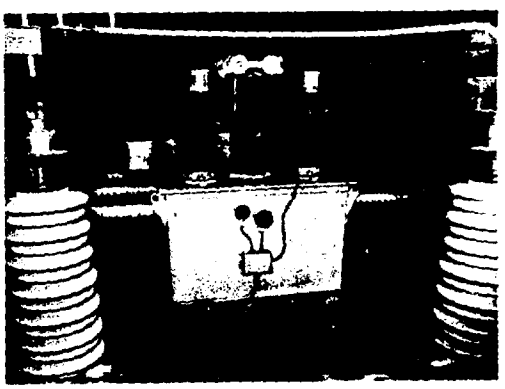

Fig. 3. Power-isolation transformer

Fig. 2. Variable voltage transformer

Fig. 4. Rectifier assembly

Fig. 5. Control panel

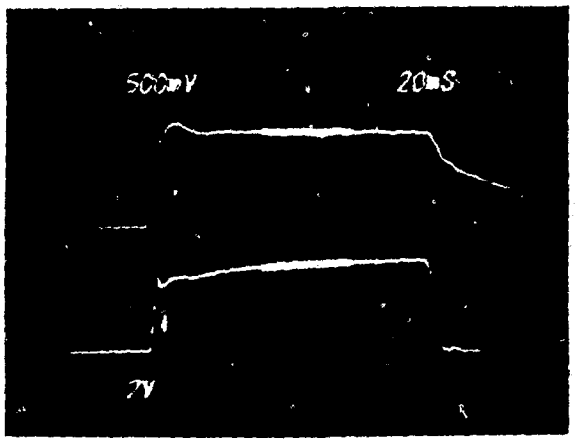

Fig. 6. Arc voltage and current waveforms