A NEW HIGH CURRENT LABORATORY AND PULSED HOMOPOLAR GENERATOR POWER SUPPLY AT THE UNIVERSITY OF TEXAS

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Summary

The University of Texas at Austin is constructing a spacious facility for research in pulse power technology at the Balcones Research Center, located in north Austin. The arrangement and capacity of the facility are intended to support high-current experiments. The laboratory power supply being designed consists of six homopolar generators, each capable of delivering ten megajoules of energy. The output bus is configured such that various series, parallel, and series-parallel circuits of homopolar generators are possible. Both resistive and inductive loads can be driven from the power supplies. Research programs will be supported with a wide range of physical facilities, including materials handling, machine shop, data acquisition and analysis, engineering and operating personnel, chemical analysis and metallurgical laboratories, and an information center. These facilities will be available to the U. S. technical community through several types of arrangements with The University through the Center for Electromechanics.

Each of the six homopolar generators is designed to deliver 1 MA at 100 V, with a maximum repetition rate of a discharge every five minutes. In addition to EM launch research and applications, other intended uses of the power supply include welding of large cross-sections of metal (up to 650 cm^2 or 100 in.^{2} of steel), generation of high magnetic fields in low-impedance magnets, and testing of high-current opening switches. Status of major elements of the project is reported.

Introduction

The University of Texas at Austin is presently constructing a research facility for the Center for Electromechanics (CEM-UT). The design of the CEM-UT facility and its variety of supporting laboratories is especially well suited to fabricate and assemble large experimental apparatus and to perform research using high electrical currents.

The power supply for this high-current laboratory is presently being engineered. The modular power supply will consist of six homopolar generators (HPGs) rated at ten megajoules (10 MJ) each. The HPGs are physically arranged to make it possible to match the requirements of resistive and inductive loads at a variety of voltage and current combinations.

The six HPGs are housed below floor level in a hexagonal pit. Each HPG is protected by an individual cover that can be removed for access or maintenance whenever necessary. For major overhaul, an entire HPG can be removed from the pit. Absence of one or more HPGs will not interfere with operation of the remaining machines.

Balcones Research Center

The Balcones Research Center (BRC), presently under development, is located eight miles north and west of the main campus of The University of Texas at Austin. The Research Center, when completed, will house several University research organizations, including the Center for Electromechanics, the Center for Energy Studies, and the Center for Fusion Engineering, on a 192-hectare (475-acre) site.

Center for Electromechanics Facility

The Center for Electromechanics will be housed in the north half of a new laboratory building that will be shared with the Center for Energy Studies. The design of the CEM-UT facility and its variety of supporting laboratories is especially well suited to fabricate and assemble large experimental apparatus and to perform research using high electrical currents.

An architect's rendering of the facility is shown in Fig. 1. The building contains over 13,500 m^2 (145,000 ft^2) of floor space. The high bay, which encloses the power supply, is 15 m (50 ft) high, has a 15 x 45 m (50 x 150 ft) floor area, and is open-ended. The high bay is served by two 22,500-kg (25-ton) bridge cranes on 45,000-kg (50-ton) rails. Truck access is provided.

The CEM-UT portion of the building is to the right in Fig. 1. In the right foreground are the CEM-UT support laboratories and office area. Among these support

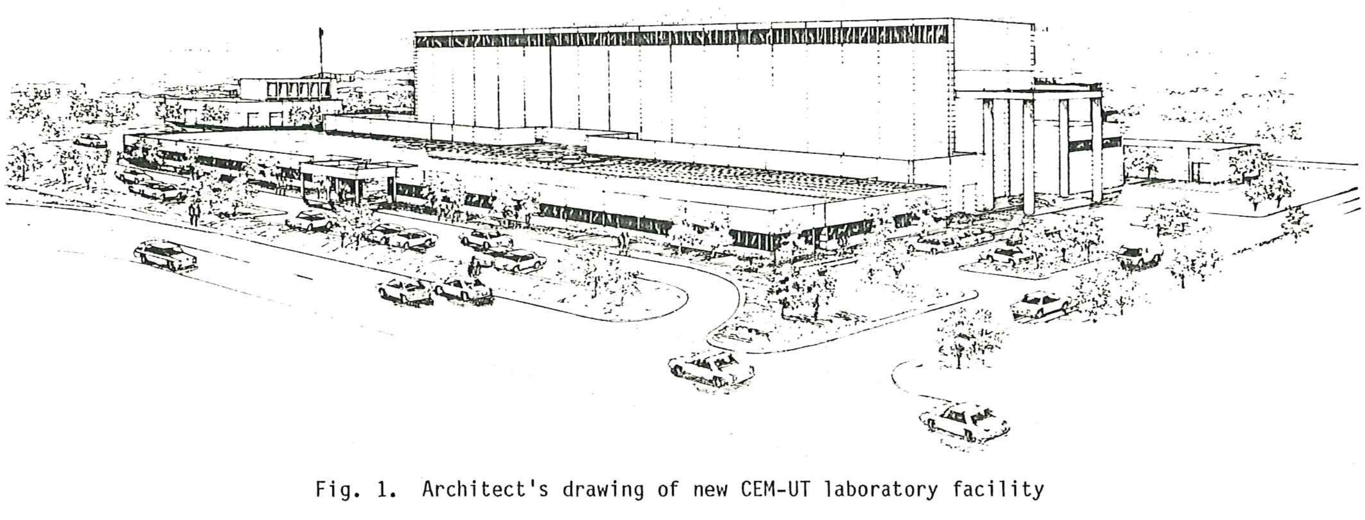

Fig. 1. Architect's drawing of new CEM-UT laboratory facility

facilities are laboratories for materials, high voltage experiments, EM launcher developoment, cryogenics, power electronics, clean assembly, rotating machinery, and tribology, a computer laboratory equipped for data acquisition and analysis, office and conference space, an electronics shop, a machine shop, and provisions for materials handling.

High Bay

The high bay is the heart of the CEM-UT experimental area. The CEM-UT half of the high bay is shown in Fig. 2. The hexagonal and round pits are visible in this figure. The hexagonal pit, 6 m (20 ft) across flats and having a maximum depth of 3.7 m (12 ft), will house the six homopolar generators (HPGs) that comprise the main pulse power supply for the laboratory. Six individual covers, each capable of supporting a 40,000-kg (9-ton) concentrated load, will shelter the six HPGs. Covers can be removed to provide access to the HPGs. Experiments can be clustered about the vertical hexagonal bus that will extend above floor level from the center of the pit. It is not anticipated that experiments will be run simultaneously, but having one experiment in place while another is running is a distinct possibility.

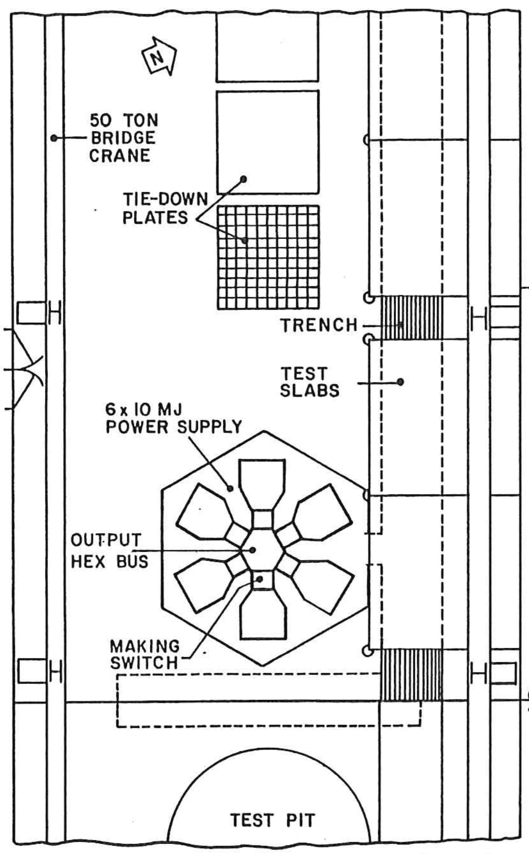

Fig. 2. Placement of 60-MJ power supply in the machine bay of CEM-UT Balcones Laboratory

The round pit, 6 m (20 ft) in diameter and 6 m (20 ft) deep and located adjacent to the power supply pit in a sheltered area immediately outside the enclosed high bay, is intended to house future experiments that may require earth shielding or water immersion.

The high bay end doors that separate the two pits can be opened to provide a 9.7-m (32-ft) wide opening to the full height of the high bay if necessary.

South of the hexagonal pit and at floor level will be four machine mounting pads, each 2.7 x 3 m (9 x 10 ft). Each mounting pad consists of a T-slotted machine base solidly connected to bedrock. Each pad can withstand a static load of 88,000 kg (20 tons) and moments of 1.36 MN•m (1,000,000 ft•lb_f) about each of three principal axes.

Power Supply Configuration

The six HPGs in the pit will have their centerlines horizontal along radial lines between the pit centerline and the pit corners. Elevation and plan views of one HPG are shown in Figs. 3 and 4. The relationship between the four output buses per HPG, the coaxial connection to the central hexagonal bus, the cover support, and the cover can also be seen. Every practical effort has been made to prevent current concentration and to retain the modular concept of the power supply. It is possible to replace the coaxial connections with making switches when the need arises. The central hexagonal bus will have a separate support structure (not shown).

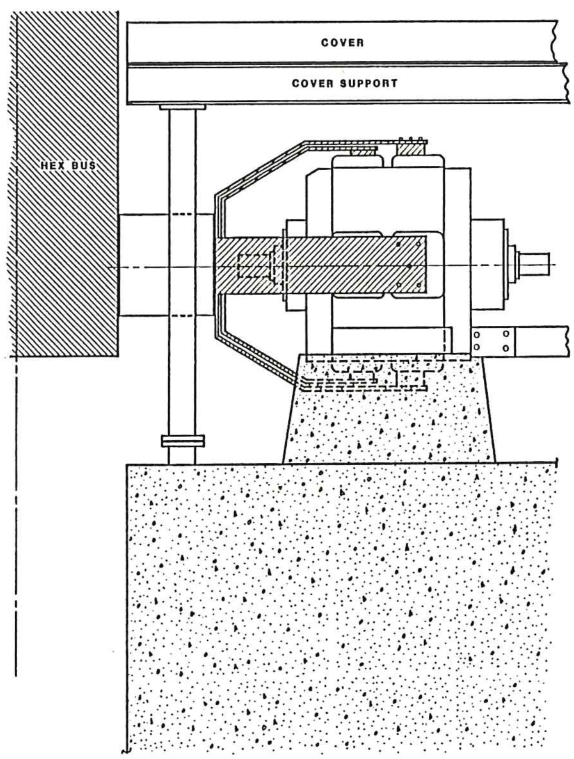

Fig. 3. Elevation view of 10-MJ HPG

Each segment of the hexagonal bus will consist of at least two 2 x 40-cm (3/4 x 16-in.) copper plates terminating above the laboratory floor. The bus will be approximately 120 cm (48 in.) across flats. As standard procedure, (1) any of the six HPGs can be used singly; (2) any symmetric pair can be connected in series or in parallel; (3) three symmetric machines can be connected in parallel; (4) four symmetric machines can be connected in series; (5) all six HPGs can be connected either in series or in parallel; or (6) two sets of three HPGs in series can be connected in parallel. These several connections will be accomplished by using different transition pieces atop the hexagonal bus. These standard connections derive from the desire to provide energy on balanced lines with center tapped ground. Other combinations are possible and will be considered on an individual basis.

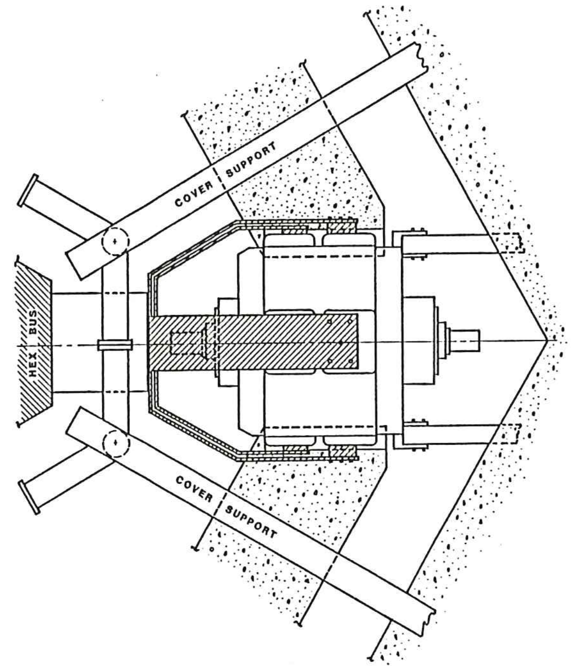

Fig. 4. Plan view of 10-MJ HPG

Power Supply Parameters

The design parameters of the power supply HPGs have been reported in some detail in a previous paper[1] and will therefore merely be summarized and updated here. Their characteristics are presented in Table 1.

Table 1. Characteristics of Balcones Homopolar Generators

Rotor Type	Truncated Drum
Rotor L/D Ratio	1.03
Bearing Type	Hydrostatic
Gross Weight, kg (lb_f)	30,800 (14,000)
Motoring Time to Full Speed, min	2
Design Speed, rpm	6,100
Capacitance, F	1,640
Resistance, μΩ	10.1
Inductance, nH	175
Peak Output Voltage per HPG, V	110
Peak Output Current per HPG, MA	1
Maximum System Voltage, V (6 HPGs in series)	660
Maximum System Current, MA (6 HPGs parallel)	5
Minimum Time Between Discharges, min	5

Speed and Field Control

Because grouped HPGs, like capacitors connected in parallel, must avoid situations in which energy is transferred among machines instead of to the load, the control system of the Balcones power supply is designed to sense and prevent such behavior. The primary control requirements are for proper matching of rotor speeds and field excitations among the active HPGs in the system. The safety of the HPGs also depends upon the integrity of the load itself; therefore, every practical measure must be taken to avoid tentative loads.

Magnetic Circuit

The magnetic circuit of each HPG consists of the stator, the end plates, and the rotor. These can be seen in cross-section in Fig. 5. There are two 60,000-At field coils per machine.

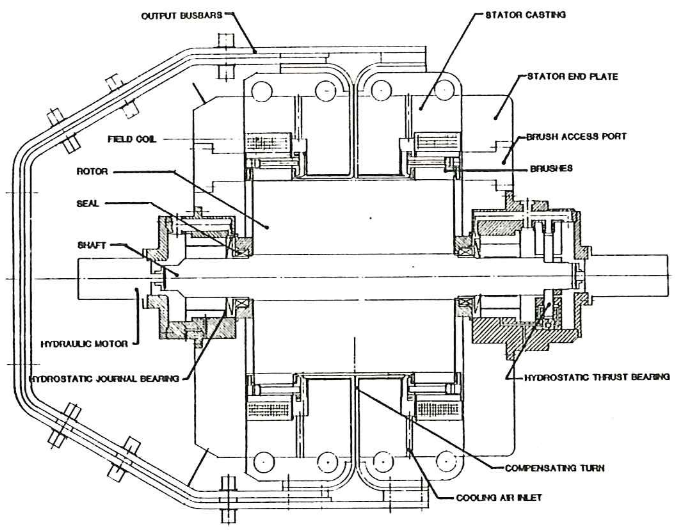

Fig. 5. Cross-sectional view of 10-MJ HPG

Brushgear

Current is collected by 42 rows of 7 Morganite CM1S copper-graphite brushes at each end of the rotor. The area of each brush is 2.4 cm^2 (0.375 $in.^2$). The baseline design requires the brushes to close the output circuit. Brushes and actuators closely resemble those of other HPGs developed by CEM-UT. Brush assemblies are supported from a novel 3-segment ringlike structure designed to allow the brushes to be removed and replaced without disassembling the bearings.

Bearings

The rotor is supported by two six-pocket hydrostatic journal bearings and one double-sided six-pocket hydrostatic thrust bearing. Bearing oil is supplied by two systems, one electric motor driven and the other steam turbine driven.

Motoring System

The rotor of each HPG is driven by two direct-coupled hydraulic motors, one at each end of the shaft. Motoring time will be two minutes.

Cooling

The minimum cycle time between rated-current discharges of the power supply system is expected to be five minutes. This limit is imposed by cooling requirements. The brushes are air-cooled. The compensating turns, field coils, bearing oil, and hydraulic oil are water-cooled.

Auxiliary Systems

The field coil power supply is located outside the high bay in the utility vault above the control room. The bearing oil system, motoring system, and air supply system are located in an auxiliary building approximately 75 m (240 piping ft) from the pit. Their location was influenced by considerations of noise, fire hazard, and personnel safety.

Overall Design Criteria

The major design criteria for the 60-MJ HPG power supply have been modularity, operational dependability, repetition rate, maintainability, simplicity of the drive train, efficiency of energy transfer to resistive and inductive loads, safety, moderate to conservative design values, and reliance on principles and technology previously proven at CEM-UT. These criteria are expressed in the easily removable air-cooled brushes, water-cooled field coils, hydraulic motor sizing and direct coupling, low-impedance removable field coils, and hydrostatic bearing design.

Present Status of the Balcones Facility

The building is presently under construction, with an expected completion date of November 1984. Engineering of the 60-MJ power supply is proceeding. Manufacture of the power supply is expected to be completed by August of 1985, with installation being completed by December of that year.

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10 MJ HOMOPOLAR GENERATOR