THE PROPOSED CEM-UT 50 MJ PULSED HOMOPOLAR GENERATOR POWER SUPPLY

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Introduction

The Center for Electromechanics at the University of Texas at Austin (CEM-UT) has been involved since 1972 both in the development of homopolar generators (HPGs) as pulsed power supplies and in the application of these power supplies to a variety of loads. We have proposed that a 50-MJ HPG system be built as an experimental power supply for future CEM-UT research and development. This system will be part of a new research facility UT plans to build for CEM-UT at the UT Balcones Research Center.

Originally the machine was to be a modified version of the 50-MJ HPG designed to power the UT Texas Experimental Tokamak (TEXT). However, recent developments by CEM-UT indicate that a modular approach offers greater performance flexibility. The attractiveness of modular construction is particularly enhanced by the concurrent development of the all-iron-rotating (AIR) HPG by CEM-UT.

Background

In 1972-74 the UT group that later became CEM-UT built two HPGs to demonstrate the principle of inertial energy storage with homopolar conversion for pulsed power generation.[1] We have continued to develop rotating machines, including the HPG, as pulsed power supplies and have explored industrial applications of pulsed power as well. Current programs include welding of large metal sections,[2,3,4] heating billets for forging and rolling,[5] and electro-discharge-sintering of powdered metals.[6]

In 1976-77 CEM-UT designed a system of four 50-MJ, 125-volt, 200-KA, HPGs as a torroidal and poloidal field power supply for TEXT.[7,8,9] This single-rotor HPG is shown in figure 1. Although the TEXT HPG was never built, we proposed to the UT administration that an

Advantages of Modular Construction

Some HPG applications, especially charging inductive stores, benefit from higher generator voltage while others, such as welding, require very high currents at low voltage. Since the design of an HPG involves trading off space for current collection against space for voltage generation, it is difficult to achieve both high current and high voltage capability in a single generator design.[10] The problem is compounded for larger machines since, for generators of a fixed geometry,

- voltage scales with rotor radius,
- current scales with rotor radius squared, and
- energy scales with rotor radius cubed.

This indicates that energy and current are much easier to achieve than voltage. By using several small machines to make the HPG power supply, one can achieve a system adaptable to a range of load requirements. Table 1 shows the advantages of modular HPG power supply construction in terms of achievable voltage and current for system storing the same total energy.

TABLE I

Maximum Voltages and Currents Available from Modularly Constructed HPG Power Supplies of the Same Total Energy

Number of generators	Maximum voltage (in series)	Maximum current (in parallel)
1	V_0	I_0
2	1.6 V_0	1.3 I_0
3	2.1 V_0	1.4 I_0
4	2.5 V_0	1.6 I_0
6	3.3 V_0	1.8 I_0
8	4.0 V_0	2.0 I_0
10	4.6 V_0	2.2 I_0
12	5.2 V_0	2.3 I_0

The development by CEM-UT of the AIR HPG[11] makes the modular power supply concept even more attractive. This 3.5-to-7-MJ AIR machine is being development with support from the U.S. Army Armament Research and Development Command (ARRADCOM) and the Defense Advanced Research Projects Agency (DARPA). It promises to be the least expensive, most compact, easiest to maintain HPG ever built. Building the CEM-UT 50-MJ HPG power supply from this ARRADCOM/DARPA AIR HPG module results in a versatile compact power supply capable of producing five times the voltage or twice the current of a single-rotor 50-MJ HPG for approximately the same cost.

An array of twelve AIR HPG modules has been selected for the proposed 50-MJ power supply. The choice of twelve units is the most practical compromise among the sometimes conflicting needs for convenient module size, system flexibility, and total energy. The characteristics of a single AIR HPG are given in table II, and the

TABLE II

AIR HPG Module Characteristics

Stored energy	5 MJ
Maximum voltage	45 V
Maximum current	750 KA
Brush-current density	10^7 amps/m^2
Magnetic field density	1.6 T
Maximum rotor speed	6425 rpm
Rotor radius	0.33 m
Approximate mass	505 kg

voltage and current combinations available through series-parallel interconnection are given in table III.

TABLE III

Terminal Voltage and Output Current Available From Modular System of 12 AIR HPGs

Modules (parallel/series)	Terminal voltage (V)	Maximum output current (MA)
12/1	45	9.0
6/2	90	4.5
4/3	134	3.0
3/4	179	2.3
2/6	269	1.5
1/12	538	0.8

Arrangement of the Proposed Modular 50-MJ Power Supply

The power supply will be located in the proposed CEM-UT building at one end of a 50-ft. wide, 50-ft. high, 150-ft. long machine bay served by a 50-ton overhead bridge crane. (See fig. 2.) The entire power supply will be mounted below floor level with a single large output terminal extending above the main floor to allow maximum experimental access to the generator output.

It is anticipated that the AIR HPG modules will be mounted vertically in counterrotating pairs in torque frames (fig. 3), which will be arranged hexagonally around the main output terminal (fig. 4). The series-parallel connections will be made by bolt-in jumpers (fig. 5).

Auxilliary System Requirements For the 50-MJ Power Supply

The AIR HPG modules will be motored to operating speed (6425 rpm) by individual, low-inertia, hydraulic motors with special valving that we believe will allow the motors to remain coupled to the HPG shafts

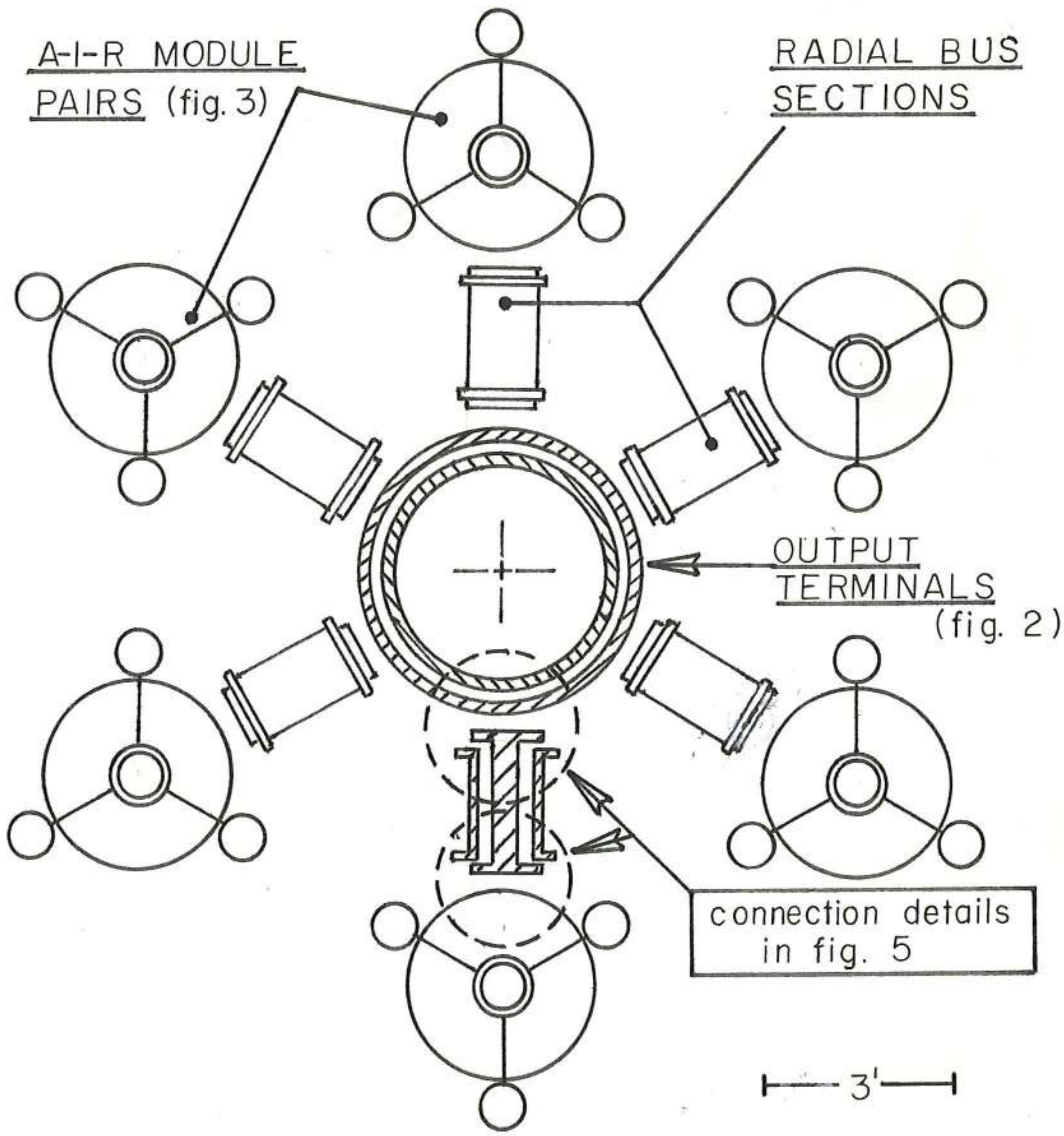

Fig. 4. Diagram of proposed HPG modular pairs surrounding central output terminals

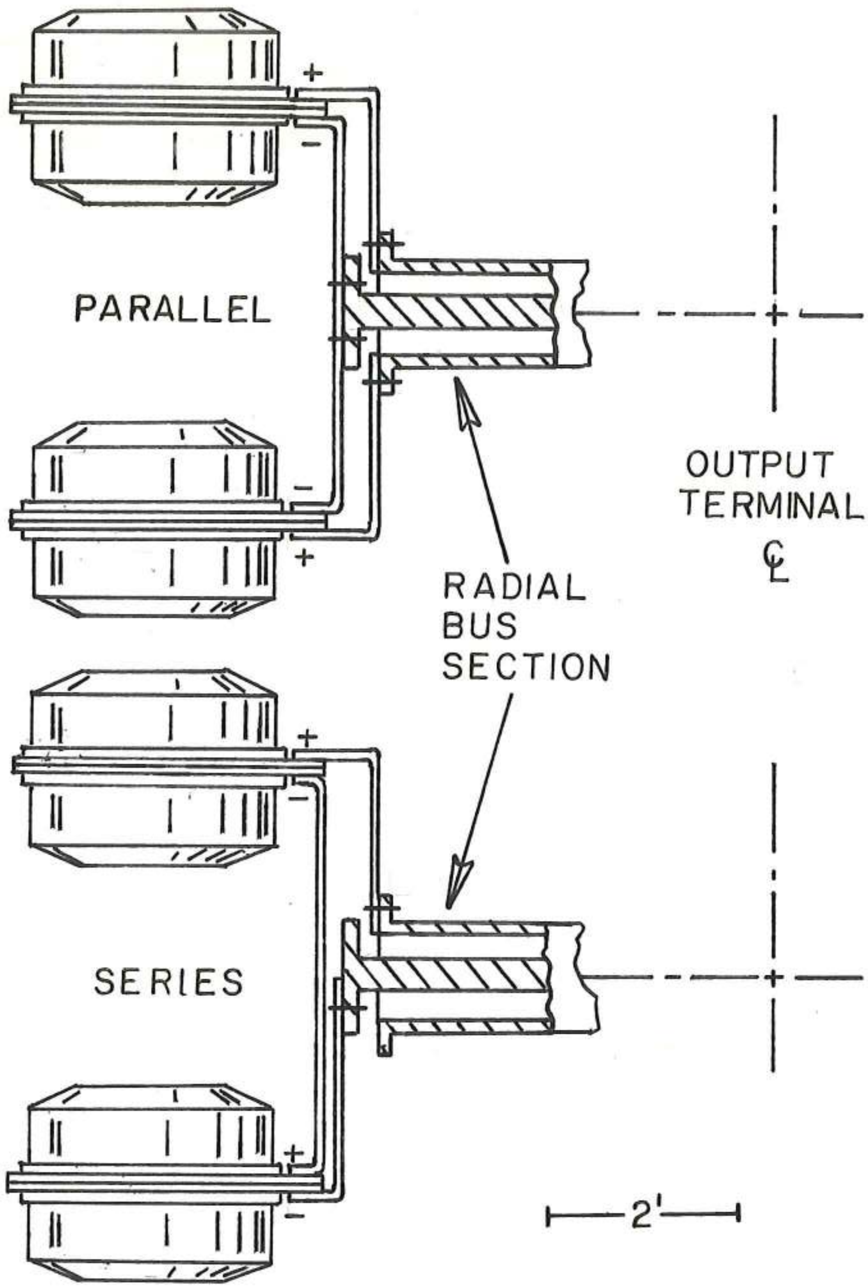

Fig. 5a. Detail of radial bus section connection at modular pair

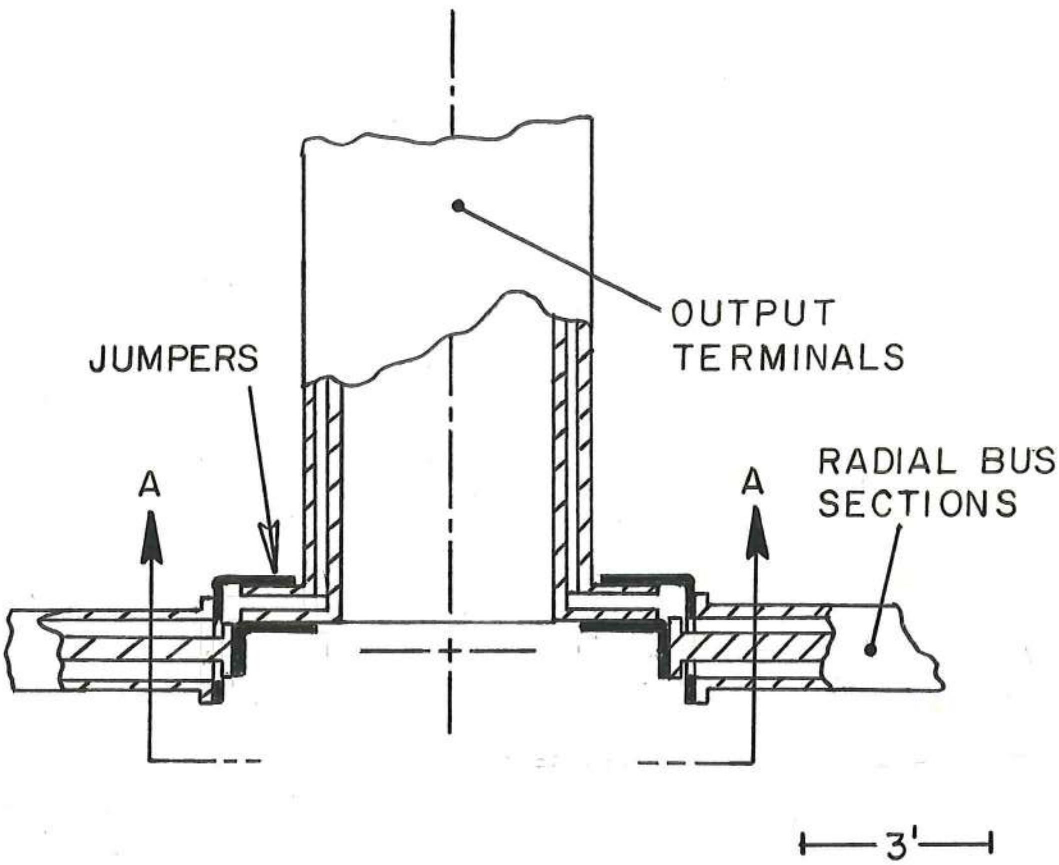

Fig. 5b. Detail of output terminal connections for parallel arrangement

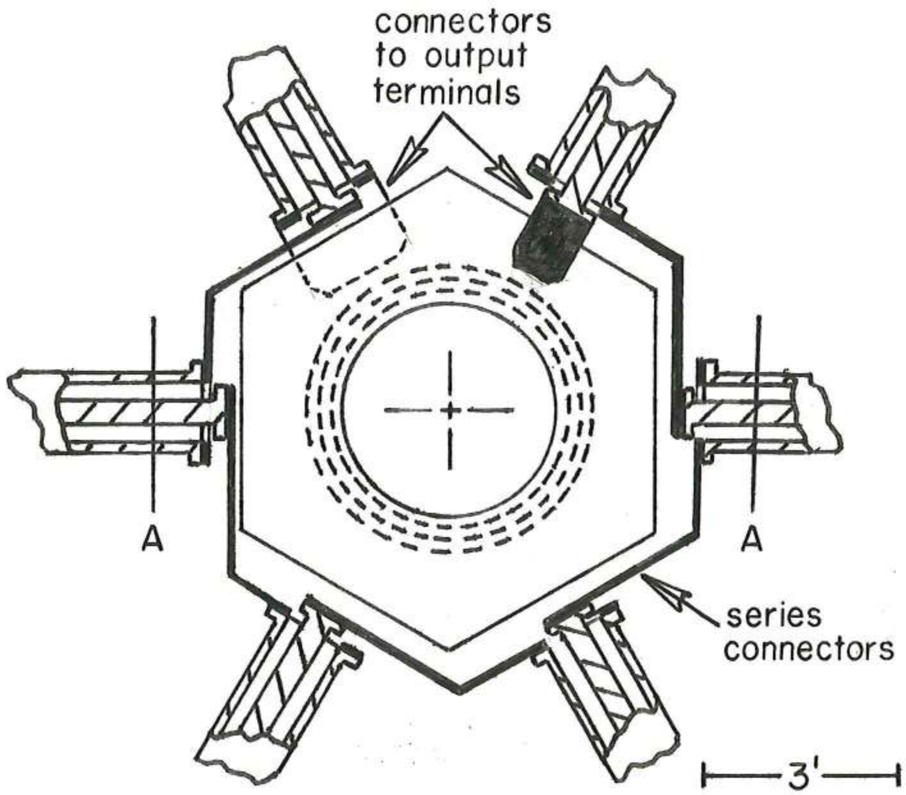

Fig. 5c. Detail of output terminal connections for series arrangement (section A-A from fig. 5b)

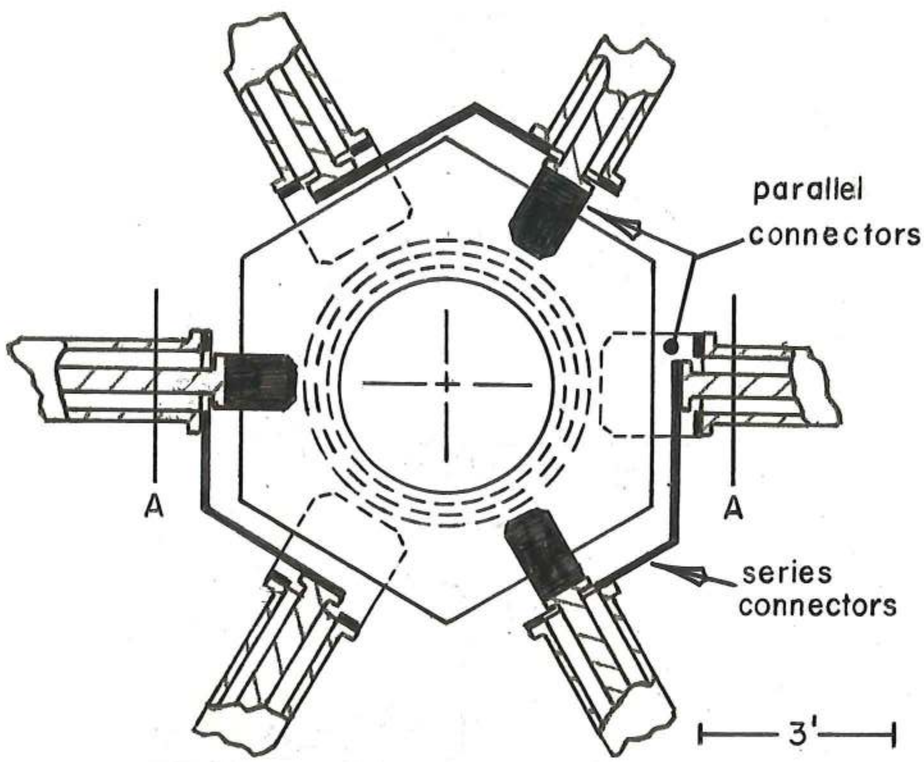

Fig. 5d. Detail of output terminal connections for series-parallel arrangement (section A-A from fig. 5b)

during a discharge. (This arrangement will be tested in the CEM-UT laboratory in the next few months.) The 50-MJ system requires approximately 1000 hydraulic horsepower to reach operating speed in two minutes. The angular-contact ball bearings used in the field-portable ARRADCOM/DARPA AIR HPG require forced oil-air mist for lubrication and cooling. Magnetic field excitation power requirements will be 30-50 kw per machine or approximately 500 kw for the system and will be supplied by an SCR-controlled dc power supply. Brushes will be pneumatically actuated, requiring ~100-psi shop air with bottled nitrogen for a back-up supply. Chilled water will be used for cooling oil, field coils, brushes, and bus bars as required. Total auxiliary requirements will be approximately 150 kw per AIR HPG module.

Conclusion

The University of Texas at Austin and the Center for Electromechanics are planning a new research facility to be located at the UT Balcones Research Center in Austin, Texas. This facility will include a versatile, high-current pulsed power supply, consisting of 12 5-MJ AIR HPG modules that can be connected in various parallel-series arrangements. A prototype AIR HPG module will be built during FY 1981 with ARRADCOM/DARPA support.

Having peak-output power in excess of 400 megawatts, the 50-MJ HPG power supply should prove extremely valuable in future high-current pulsed power experiments, including welding, heating, metal forming, switch-gear testing, and electromagnetic propulsion.

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