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Equipment, Methods, and Techniques

AEC Research and Development Report

PARALLEL OPERATION OF WELDING GENERATORS

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Laboratory Services Division

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ABSTRACT

Eight 900-ampere, 36-kw direct current welding generators driven by eight 60-hp induction motors have been operated in parallel to supply up to 7200 amperes to resistance loads for heat transfer studies. Details are given for this unique installation, which provides safety interlocks and permits sectionalized operation for smaller, separate loads.

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PARALLEL OPERATION OF WELDING GENERATORS

INTRODUCTION

Studies of the heat transfer characteristics of various reactor components are conducted at the Savannah River Laboratory. Experimental temperature conditions are obtained by inserting the component to be tested in a DC circuit and using the resistance of the test piece to raise the temperature. A flexible DC power source was required to meet the experimental demands.

Initially, a power source had been provided that consisted of two 900-ampere DC welding generators. These generators were operated in parallel from only one built-in exciter. Experience with this unit demonstrated its practicality, flexibility, and economy.

The need to reach higher temperatures and greater heat fluxes required the installation of a larger power source (7200 amperes at 40 volts). Since the total power available in such a source would be used intermittently, and since a demand existed for smaller units of power, some system of sectionalizing this source appeared to be desirable.

Several types of commercially available power sources were considered; however, a system, similar to the original installation, with eight instead of two 900-ampere generators, was selected because of its low initial cost, potential flexibility, and shorter delivery time.

SUMMARY

Eight 900-ampere welding generators have been installed to provide to various loads an electrical input up to 7200 amperes of direct current at 40 volts. The power, control, exciter, and output circuits have been designed for complete parallel operation. The excitation scheme utilized in the original installation (i.e., one built-in exciter used with two generators) could not be extended to eight generators because the exciter capacity was inadequate. This problem was solved by designing an interlocked AC power supply, a parallel DC bus system, and a special parallel exciter circuit including an equalizer bus. The design also includes arrangements that permit the simultaneous operation of individual generators or groups of generators on as many as three separate loads.

These eight machines are each driven by 60-hp induction motors that are provided with safety interlocks to prevent startup or to disconnect all motors in the event of erroneous connection to the direct current buses.

As far as can be determined this is a unique installation that provides an economical, flexible, and safe DC power source. Operating experience has been satisfactory. The equipment has been used to supply more

than 6800 amperes to a single load for approximately 30 minutes per experiment and to supply power to three separate loads simultaneously.

DISCUSSION

GENERAL

A facility to produce up to 7200 amperes of direct current was required for heat transfer experiments. Design criteria stressed early installation, safety of operation, and practical economy.

A small facility existed that consisted of two 900-ampere DC welding generators operated in parallel from one exciter. Cost estimates indicated that the addition of identical generators to the existing facility would be the most economical and the quickest method of producing the required power. However, it was not known whether eight similar welding generators could be operated in parallel. The equipment manufacturer recommended that not more than three machines be connected in parallel and that these should be excited from only one of the three built-in exciters. No example of true parallel operation of 900-ampere DC welding machines was found in the literature[1,2,3]. However, observations from tests conducted on the two existing machines indicated that complete parallel operation for multiple machines should be successful.

The decision was made to proceed with the design and procurement necessary to install eight 60-hp, 36-kw DC welding generator sets for complete parallel operation. Complete parallel operation is construed to include paralleled prime movers, paralleled direct current output from the generators, and the use of eight built-in exciters operating in parallel.

The eight-generator assembly may also be operated as a single power source or sectionalized into several smaller units. These smaller units can be operated simultaneously or separately. The circuits are shown in Figures 1, 2, and 3.

EQUIPMENT

The equipment in this system consists of the primary power supply apparatus, the welding generator sets, the DC bus and excitation systems, the metering equipment, and the control apparatus. Conventional power supply and control apparatus was used throughout the system. The components of the system are discussed briefly below.

The primary power is supplied from the substation via conventional feeder apparatus to four circuit breakers (one for each two machines) and from these to eight 480-volt, three-phase motor starters. Details are shown in Figure 1.

There are eight welding generator sets. Each machine embodies a 60-hp induction motor, a 36-kw direct current welding generator, and a 1.5-kw direct current exciter generator. The rated output from each machine is 900 amperes of direct current at approximately 40 volts. The eight motor-generator sets were mounted on "Unisorb" felt pads for noise reduction purposes. (See Figures 1 and 2.)

The direct current bus system is designed to handle 8000 amperes. It is arranged to permit sectionalizing to the extent required for use in as many as three simultaneous experiments. Sectionalization is accomplished by manually rearranging special links in the 1/4 x 4-inch electrical-grade copper bars. Figure 2 shows the possible arrangement and the paralleled excitation circuits.

The metering equipment consists of three voltmeters and five ammeters with shunts. The voltmeters are connected to coordinate with the bus sectionalization scheme for use in as many as three separate experiments. Two of the ammeters are used in conjunction with two rotary switches to monitor the output currents from each of the generators at two separate operating stations. The other ammeters are used for metering combined currents to the various experiments, and their connections can be manually altered as required. Provisions were made to use an 8000-ampere shunt and ammeter, but these were not installed. Figure 2 shows the locations of the ammeter shunts.

The control apparatus consists of two stations: one is adjacent to the generator sets and the other is remotely located. These two stations house conventional control equipment that provides selective means for locally or remotely operating the various generators as required by the operating setup. These stations also house the safety interlock terminals whereby each separate experiment can be interlocked into the controls to shut the generators down in the event of excess temperature, low water flow, or other undesirable experimental conditions.

OPERATION

A "load specimen" is fabricated to represent accurately the "unknown" for heat transfer studies.[4,5] This load specimen is connected in the direct current circuit as a load resistance. Manual rearrangements of the buses and meter connections are made as required for the particular experimental setup. Flow switches, temperature-measuring devices, pressure switches, and the like are connected into the control terminals as desired for safe control and data accumulation.

When the setup has been completed, all control rheostats are set to their lower limits and the main power circuit breakers are closed. The machines are then started and the excitation circuit breakers are closed. Direct current power to the experimental load (or loads) is gradually built up to the desired level by simultaneous rheostat changes at the remote control station.

As the machines warm up under load, slight differences in circuit resistances occur to cause a spread in current output from the individual machines. This spread in current output is eliminated by small adjustments to the series field rheostats. These fluctuations have not been large enough to actuate the protective equipment designed to interrupt power to the machines.

SAFETY DEVICES

Combination temperature and overload detectors were provided within each machine and were connected within the control circuits to provide positive stopping of all generator sets involved in any experimental group when any one machine failed.

Successful operation of the groups of machines depends upon several secondary safety interlocks, such as temperature, pressure, or flow switches, located in or adjacent to the experimental load. These are connected in the control circuit through special terminals. Adverse actuation of any one interlock will shut the affected group of generators down. The interlocks may be omitted when they are not required for personnel safety or for protection of equipment.

Reversed polarity within the excitation circuit is prevented by the use of one-time fuses in each exciter lead and by circuit breakers for each of the possible generator groups.

Remote and local "panic" buttons have been provided in easily accessible locations. Either button will stop all of the motor generator sets at once during an emergency situation.

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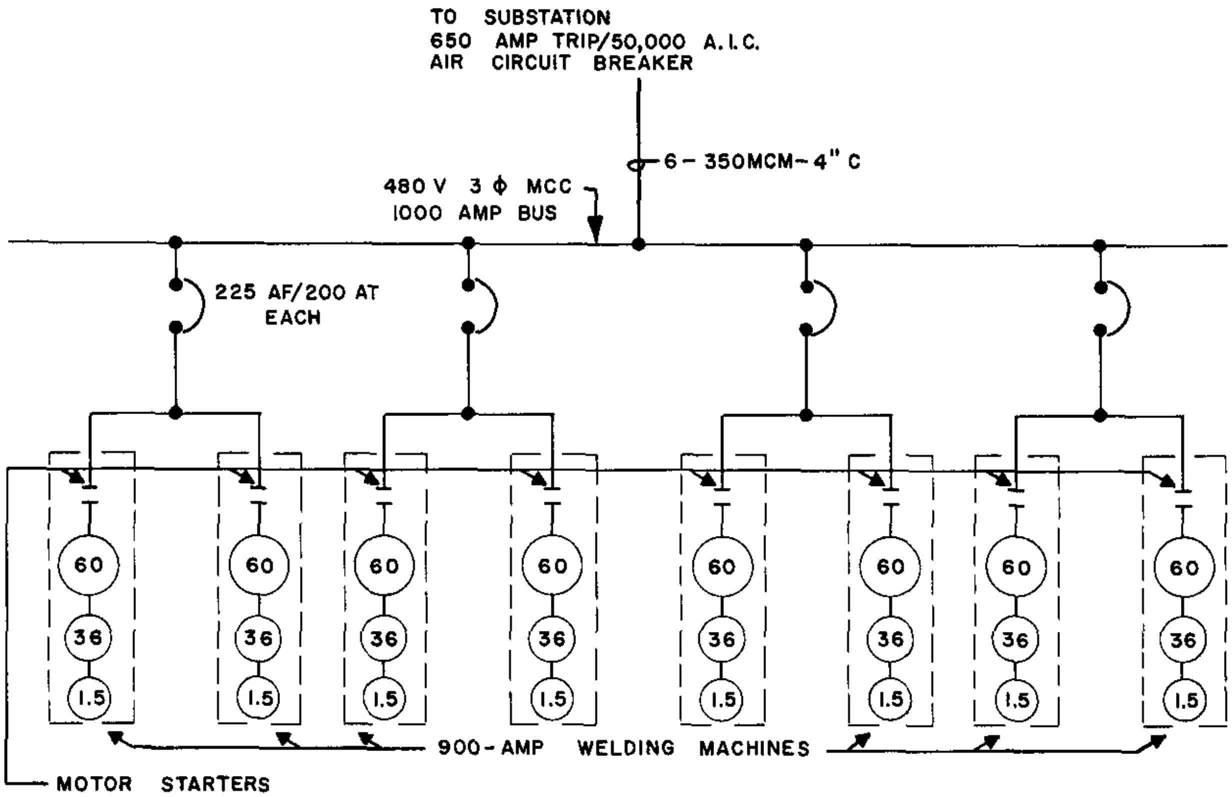


FIG. 1 SINGLE LINE DIAGRAM - ELECTRICAL

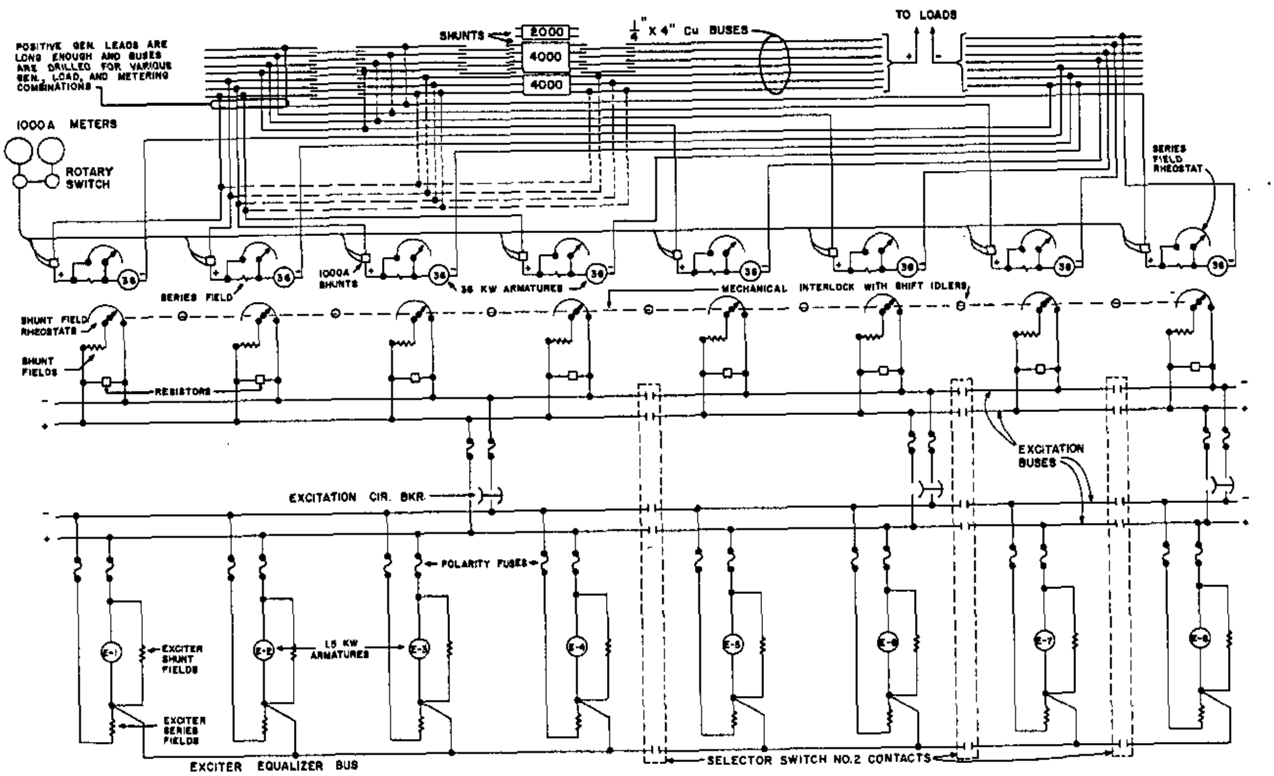
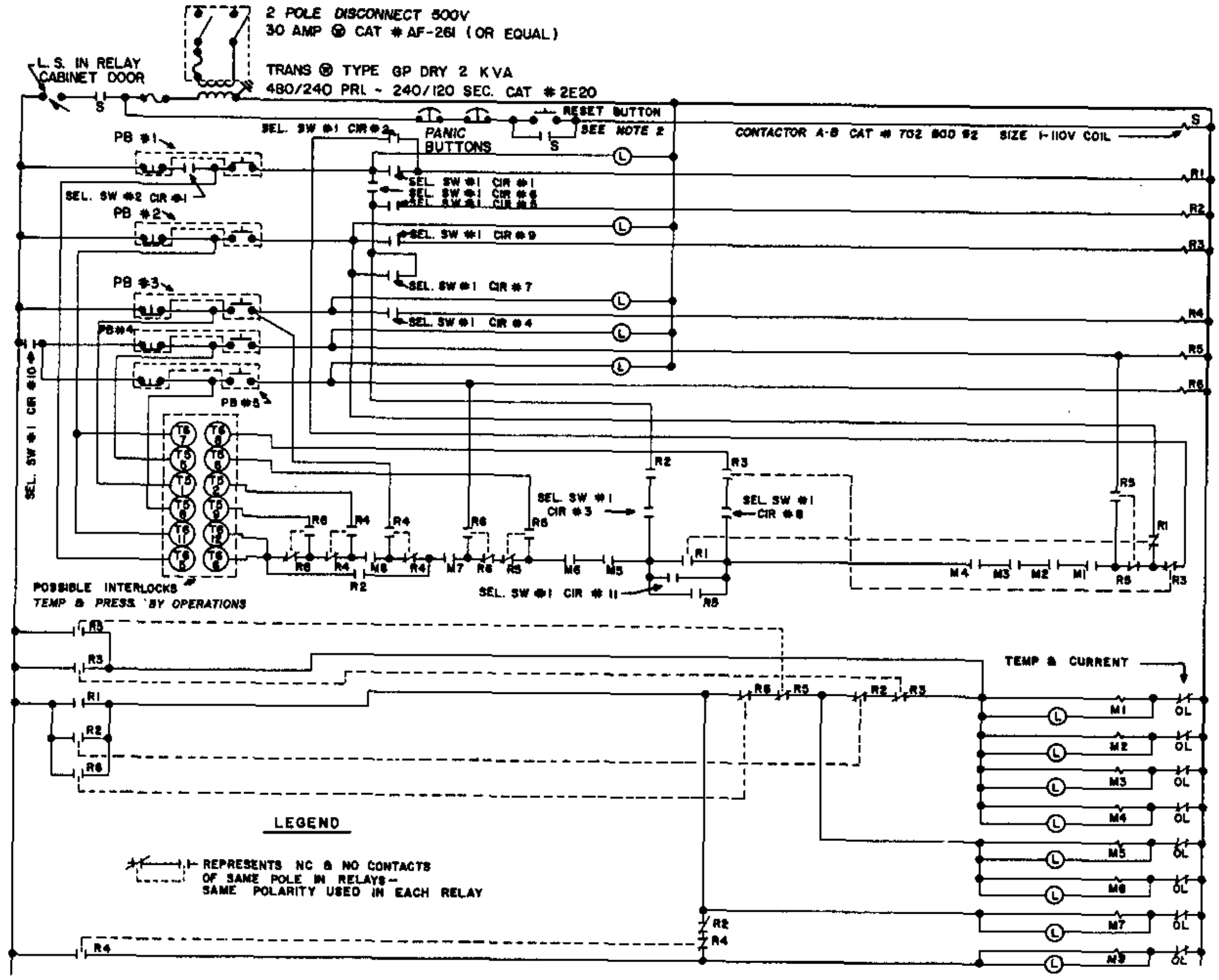


FIG. 2 PARALLELING DIAGRAM – DIRECT CURRENT APPARATUS



SEL. SW. NO. 1

CIR NO.	POSITIONS 1	2	3	4	5
1	■				
2	■				
3			■		
4		■	■		
5		■	■		
6			■		
7		■			
8			■		
9		■	■		
10				■	
11		■			
12	■	■	■		

CKT 12 IS SPARE

SEL. SW. NO. 2

CIR NO.	POSITIONS 1	2	3	4	5
1	■	■	■		
2	■			■	
3	■			■	
4	■			■	
5	■			■	
6	■			■	
7	■	■	■		
8	■	■	■		
9	■	■	■		
10	■	■	■		
11	■	■	■		
12	■	■		■	
13	■	■		■	
14	■	■		■	
15	■	■		■	
16	■	■		■	

OPERATING COMBINATIONS PROVIDED FOR

ALL JUMPERS AND/OR EXTERNAL INTERLOCK CIR. MUST BE REMOVED FROM INTERLOCK TERMINALS EXCEPT THOSE DESIGNATED FOR EACH COMB.

TO RUN GEN NO.	POS OF SEL SW1	POS OF SEL SW2	PULL IDLERS OUT	USE PB NO.	USE INT-LOCK TERM. NO. T5	T6	RELAY ACTUAT. NO.	NO. OF GEN. RUN
1-8	1	1		1	-	5-6	R1	8
1-7	2	2	G-K	2	-	11-12	R2-R3	7
8	2	2	G-K	3	1-2	-	R4	1
1-4	3	3	K-B-J-G	2	-	7-8	R3	4
5-7	3	3	B-J-K-G	1	-	5-6	R2	3
8	3	3	B-G-K-J	3	1-2	-	R4	1
1-6	4	4	C-K	4	5-6	-	R5	6
7-8	4	4	C-K	5	8-9	-	R6	2

NOTES:

1. All wiring and components were connected exactly as shown to provide flexibility between gens.
2. Panic button interrupts all gens. Reset button was used to restart all combinations.
3. Relays R1-R6 to be Allen Bradley bulletin BX440 with 110 v operating coils (or equal). Both the NO & NC contacts were usable on one potential.
4. The cams of the selector switches were cut to close contacts as shown by shaded spaces.
5. Control panel, terminal block Nos., and terminal Nos. where shown on this dwg. are encircled thus

(T6 / 5) Terminal block No. 6
Terminal No. 5

FIG. 3 CONTROL DIAGRAM – SCHEMATIC