LEGIBILITY NOTICE

A major purpose of the Technical Information Center is to provide the broadest dissemination possible of information contained in DOE's Research and Development Reports to business, industry, the academic community, and federal, state and local governments.

Although a small portion of this report is not reproducible, it is being made available to expedite the availability of information on the research discussed herein.

NOV 06 1989

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

LA-UR--89-3277

DE90 002350

TITLE: A COST EFFECTIVE BATTERY BANK FOR I^2T TESTING AND
EVALUATION OF ELECTRICAL SWITCHGEAR

AUTHOR(S): REASS, W.A., CTR-4

SUBMITTED TO presented to IEEE 13th Symposium on Fusion Engineering,
Knoxville, TN, October 2-6, 1989

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

By acceptance of this article the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution or to allow others to do so for U.S. Government purposes.

The Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy.

Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545
MASTER 48

A COST EFFECTIVE BATTERY BANK FOR I^2t TESTING AND EVALUATION OF ELECTRICAL SWITCHGEAR†

W. A. Reass

Los Alamos National Laboratory, Los Alamos, NM 87545

ABSTRACT

This paper describes the electrical design and mechanical construction of a 50 kA "step switched" battery bank. Individual fuses protect each of the forty parallel isolated strings of three series (12 V) batteries. Step current waveforms of 12.5 kA, 25 kA, 37.5 kA, and 50 kA are produced by 8 sets of pneumatically driven 20 pole step switches and current limiting stainless steel "trombone" resistors. Inexpensive, yet conservatively designed, Group 65 Motorcraft car batteries are used to give an I^2t capability of better than 5×10^9 . The battery bank has well over 1500 shots, with testing of commercial switchgear continuing. In addition to the battery bank engineering data, results of repetitive testing of vacuum interrupters at their I^2t limit will be provided.

INTRODUCTION

A 50 kA battery bank was designed and built at Los Alamos as a cost effective alternative to commercial power supplies. The battery bank is used to test, evaluate, and characterize the electrical and thermal properties of AC rated switchgear (i.e., 2 kA to 4 kA devices) with long duration (to 5 seconds) current pulses up to the 50 kA level. As the switchgear is also subjected to high voltage waveforms (~50 kV), an added plus of the battery bank is that it would more easily survive a control fault or H.V. arc-over than an SCR or diode driven dc supply.

BATTERIES

The primary concern with any bank system, once the desired characteristics are identified, is to find the right battery. Los Alamos desired a battery with high discharge capability for the up to 5 second current pulses, which was cost efficient and physically small. Because the repetition rate was low with a 5-10 min recharge time, it was felt deep discharge marine or large truck batteries could be avoided. Although currents of up to 50 kA are being generated, the actual amp-hour draw per battery string is rather low (~1.5). After careful examination of the car battery data, and discussion with manufacturers, batteries were purchased and tested. We found the Globe National "GP 65-ACFM65J" to be the best for this use, and encountered no problems during testing. It was also encouraging to find Eglin Air Force Base at Fort Walton Beach, Florida, to be using these batteries to generate megamp level currents for rail gun experiments. Given in Table 1 is a list of some of the more important battery parameters. It is significant to note the low internal resistance and hefty internal copper (lead coated) intercell connections. For the Los Alamos battery bank design we chose a peak discharge current of 1250 amps per battery string, well within the 1600 amp rating as shown in Fig. 1. Used to protect each of the 40 parallel battery strings, Gould A25X 800 amp semiconductor fuses will clear 3 kA faults quickly, but reliably hold the 50% (1250 amp) overcurrent for 5 seconds (Fig. 2).

† Work performed under the auspices of the US DOE

SWITCHING

Switching is performed by Los Alamos designed pneumatically operated 20 pole step switches. Evaluation of commercial heavy duty, single pole, 400 amp aircraft contactors indicated a short contact life (20 shots) when operated at the 1250 amp level. By utilizing 20 pole switches, significant simplification of control circuitry is achieved. Figure 3 shows the contact material made from 1" wide copper bus bars. The electrodes are silver plated to prevent contact oxidation. These moving electrodes are self-aligning, Belleville washers permit the individual electrode to close on unevenly aligned fixed contacts. The Belleville washers also serve to compensate for the different vertical clearance between poles. To further reduce alignment problems, the air pistons are connected to the "drive plate" with ball and socket joints. For a rigid support assembly, G-10 fiberglass is used throughout. Photograph 1 shows the step switches, associated air reservoirs, and four-way control valves. In Photo 2, a view of the 50 kA step switch is shown after 1,500 operations. These contacts may seem to be in rather poor condition, but actually, are in remarkably good condition.

CONSTRUCTIONAL FEATURES AND PERFORMANCE

Construction Features	Gp 65-ACFM65J
Cost	40
Battery Size - inches L x W x H	11.38 x 7.5 x 7.56
Number of plates per cell	9P/10N
Plate area per cell - in. ² Pos/Neg	451/451
Diameter of Intercell Connector (in.)	0.437
Minimal diameter of terminal post (in.)	0.44
Total dry weight (lbs)	37.65
Total wet weight (lbs)	50.0
Resistance at 75°F (mΩ)	3.55
20 hour capacity - AH (1.75 VPC cutoff)	84
25 amp discharge capacity (1.75 VPC cutoff)	
- minutes	165
- AH	68.8
BCI - cold crank amps at 0°F	875

Photo 1.

FIG. 3

Photo 2.

CIRCUIT

The electrical circuit is shown in Fig. 4, each string of 3 series batteries includes the 800 amp fuse, four step switch, and four water-cooled stainless steel trombone resistors. Resistance valves are chosen to give current steps of 312, 625, 938, and 1250 amperes (per string). All battery strings are "switched," providing equal discharge and charge curves. Although not shown, batteries are recharged from a surplus arc-welder. Charge currents are equalized through resistor diode networks. A 50 kA, 50 kV isolation switch of Los Alamos design is used to protect the battery bank from other test (HV) waveforms. This switch is not specifically designed to make or break current, and is the subject of the paper "High Speed Transfer Switch With 50 kA and 50 kV Ratings."

FIG. 4

RESULTS

The battery bank has been very reliable with about 1,500 full current operations. I^2T waveforms of 2.5×10^9 and 5×10^9 (Fig. 5 and 6) are routinely used to test our Siemens D-10 vacuum interrupters. With the appropriate diagnostics, such items as long term thermal equilibrium properties can be determined along with pre- and post- I^2T resistance effects as shown in Figs. 7 and 8.

FIG. 5

FIG. 6

PRE & POST I^2T CONTACT RESISTANCE (3 BOTTLES)

FIG. 7

SWITCH VOLTAGE DROP AND RESULTANT RESISTANCE

FIG. 8

CONCLUSION

This battery bank has shown to be a very reliable and cost effective alternative to commercial 50 kA power supplies. Battery bank technology is well developed and easily understood. It is a suitable technology for testing AC rated switchgear for the high current DC circuits required of present and future fusion experiments.