**Report
for**

**RESEARCH
AND
DEVELOPMENT**

➔ GOULD-BROWN BOVERI

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May 18, 1979

Dr. Russell Eaton, III
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Washington, D.C. 20545

*Don't present
Need Patent Clearance*

SUBJECT: D.O.E. Contract # ET-78-C-01-3015

MASTER MASTER

Dear Russ:

I enclose one copy of the Third Quarterly Report on the Superconducting Fault Current Limiter project. The balance of nine copies are being mailed separately. This is the number specified in the contract; please let me know if you need more copies.

We have attempted to give a thorough presentation of our work during this quarter, but I would, of course be pleased to discuss with you any aspect of this effort in more detail.

Sincerely yours,

DB Miller

D. B. Miller
Project Manager

DBM/rk

Enclosure

cc: R. E. Kennon, EPRI
P. L. Kolarik, Philadelphia Electric
Technical Information Center, Oak Ridge, TN
S. M. Hansen, DOE/Energy Technology Systems

D.O.E. CONTRACT ET-78-C-01-3015

SUPERCONDUCTING FAULT CURRENT LIMITER

Third Quarterly Technical Progress Report

February 8, 1979 - May 7, 1979

Prepared by

GOULD - BROWN BOVERI

950 9763

Prepared for

DEPARTMENT OF ENERGY
ELECTRICAL ENERGY SYSTEMS

PROJECT MANAGER

Russell Eaton, III

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1. SUMMARY AND FORECAST

During the first two quarters of this program, considerable effort was invested in determining performance objectives for SCFCLs and deciding what would be the best design concept for a SCFCL device. This third quarter has been a period of starting new long-range programs based on the decisions made in the earlier quarters. Because of the long-term nature of these studies, there are no specific results yet to report. The following paragraphs and sections describe the three major programs which are now under way.

An investigation is now in progress to determine whether there is an advantage to using SCFCLs with superconducting generators and transformers. SCFCL performance objectives specifically for these applications will be established.

A detailed device analysis of the magnetically-switched, resistive SCFCL has been started. The objective of this analysis will be to determine a complete device design, including size, shape, material and operating characteristics, for a typical set of performance specifications.

An experimental facility is now being prepared to make key measurements of switching and thermal recovery speeds for the magnetically-switched, resistive concept.

During the next quarter, substantial progress is expected on all three of these activities. Meetings will be held with contractors on the superconducting generator and transformer projects. Theoretical descriptions of the transient heat transfer and circuit behavior should be nearly complete.

1. (continued)

The experimental equipment should be completely assembled and ready for initial check out measurements.

2. PERFORMANCE OBJECTIVES - SUPERCONDUCTING MACHINES

In the Second Quarterly Report for this project, performance objectives of SCFCL's were derived, using the "Philadelphia Electric" model system in which ten, 1000 MVA, superconducting generators feed a load through three parallel superconducting transmission lines. Three location strategies for the SCFCLs were employed, but in all cases they were considered to be at the substation voltage (140kV, rms, line-to-neutral), and the limiting element was the circuit breaker for which the current had to be held below 100 kA, rms, symmetrical.

A second mode of application is now being pursued, in which the SCFCL is closely coupled with a superconducting generator, and its immediate objective is to protect the machine rather than the circuit breaker. This line of investigation will undoubtedly result in a SCFCL with a set of performance requirements which differ considerably from those derived for the Second Quarterly applications.

We are currently in communication with Massachusetts Institute of Technology and Westinghouse Electric Corporation personnel to identify the SCFCL specifications which are required for protection of the superconducting machines. This is a project which will continue at least through the next quarter and there are not yet any results to report. The following considerations will be taken into account:

1. To what extent in time and magnitude should the fault current be limited in order to be of use in simplifying the design of the machine?
2. What current limiting resistance is needed to achieve the desired limited current?

2. (continued)

3. With a resistive fault current limiter in series with the machine, can transient stability be maintained with larger subtransient reactance, and does this larger X_s'' help in the design of the machine?
4. Is the effective inertia constant of a turbine and superconducting machine lower than for conventional machines, and does this effect the transient stability situation?
5. Where is the best location for the SCFCL?
6. Can superconducting machines be expected in the near future (20 years) to operate at higher MVAs and voltages than present conventional machines?

3. DETAILED ANALYTICAL STUDY OF THE "MOST PROMISING" (RESISTIVE) SCFCL

The basic resistive fault current limiter is shown in Figure 3-1. The normal current flows through the zero resistance superconducting element, but when a fault appears, the superconducting element is converted to its normal state, and the (limited) fault current flows through the fixed shunt resistance. The most promising method of converting the element from superconducting to normal is to use a pulsed magnetic field, which elevates the type II superconductor into its mixed state region, where the loss in the now non-zero resistance rapidly heats the element to its fully-normal, high-resistance state.

A more complete diagram for the magnetically-switched resistive SCFCL is shown in Figure 3-2. A detailed analytical study of each element of this device is planned, in order to better understand its operating principles, to aid in designing and interpreting the key experiments, and to design future SCFCL devices to meet specific performance specifications.

The most important analytical studies have already been started. The first of these has the objective of describing the heat transfer from the superconducting element to the helium. Another study already started seeks a solution to the transient circuit, including realistic inductances, time-changing element resistance, and a shunt capacitance for over-voltage control. These two studies are intimately interrelated, because the current, heat flow, temperature and resistance all depend on one another.

Shunt Resistor R_{SH} (1 - 10 Ω)

Superconducting Film R_{SC}

(0 Ω - No Fault)

(10K Ω Typical with Fault)

Figure 3 - 1

Basic Superconducting Fault Current Limiter

Components

1. Superconducting Film (R_{SC})
2. Shunt Resistor (R_{SH})
3. Shunt Capacitor
4. Isolation Switch
5. Cryostat
6. Coil
7. Refrigerator
8. Fault Sensor
9. Relay & Trigger
10. Field Drive Circuit

Figure 3 - 2

Complete Diagram for Magnetically switched, Resistive superconducting
Fault Current Limiter

3. (continued)

The speed with which the element resistance must rise, transferring current into the shunt resistor, is determined by how much heat the helium adjacent to the element can absorb. This heat transfer process is very complex and not clearly understood, but considerable research is reported in the literature and the key experiments now being developed will give further data on which to base our analysis.

Some study has also been given to the coil which produces the switching magnetic field. Its shape, and size must be based on the required size and shape of the superconducting element, helium channel and cryostat.

The remaining components in Figure 3-2 will be considered in turn.

4. KEY EXPERIMENT

An experiment is now being designed and assembled at Argonne National Laboratories to determine the basic feasibility of the magnetically-switched resistive superconducting fault current limiter. A thin film ribbon of superconductor will be used which has sufficient width and length to show that the switching from the superconducting to the normal state does not depend on the slow thermal propagation process but happens rapidly enough for SCFCL requirements. Heat transfer from the normal thin film to the liquid helium and speed of recovery back to the superconducting state will also be measured.

A site for the experiment has been located. Essential equipment and instruments are on hand or have been ordered. Methods of making electrical contact with the thin film superconductor are now being developed. Both soldering and spot welding techniques are being investigated.