AN ASSESSMENT OF RESEARCH DIRECTIONS
FOR HIGH VOLTAGE DIRECT CURRENT
POWER SYSTEMS

MASTER

Quarterly Technical Progress Report
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ABSTRACT

The activity reported herein is the proposed system study to examine the dynamic relationship of integrated ac/dc systems wherein the existence of direct current circuit breakers is postulated.

QUARTERLY REPORT

This is the seventh quarterly report under Contract No. DE-AC02-78ET29185 "An Assessment of Research Directions for High Voltage Direct Current Power Systems." The objective of the study, as quoted from the statement of work in the original proposal, is "to identify hardware developments and, where appropriate, system applications which can exemplify cost and operational advantages of integrated ac/dc power systems."

INTRODUCTION

The problem is straightforwardly stated: Under what conditions will a high voltage direct current circuit breaker be needed? What ratings must it have regarding speed of operation, energy absorption, continuous and interrupting current, and voltage? What manner of systems can we anticipate will require a dc breaker? What will be the effects of breaker design and operating parameters on these systems? What control methodology should be applied for the integrated ac system/dc system/dc breaker? What application time frame are we considering?

It is this writer's opinion that it is not now possible to adequately answer any of these questions. A considerable body of literature exists on the subject 1-5, yet no definitive study exists. Clearly, research should be initiated on the fundamentals of direct current interruption and on the development and testing of a prototype. In parallel with this research, a comprehensive system can answer the initial question of need for a dc breaker.

OBJECTIVE

The objective of this study is to examine the dynamic relationships of integrated ac/dc systems wherein the existence of direct current circuit breakers is postulated. Realistic systems are to be studied, the principal goal being to ascertain the relationships between dc circuit breaker design and operating parameters (including especially speed), dc system control philosophy, and ac system parameters (including especially stability).

There are two principal areas of interest which should result from this study:

1. Specific systems are to be investigated; system-specific results are to be obtained, generalize at your own risk.
2. A methodology is to be developed; i.e., it should be possible to apply the procedures developed in this study to any potential integrated ac/dc system wherein the use of dc breakers is postulated.

SYSTEM CONFIGURATIONS

Let us be clear as to what we mean by the term "direct current circuit breaker." There are three classifications of said device:

1. Fast - interrupter - a device which catches the fault current on the rise,
2. Slow - load break - a device which waits for system controls to depress the dc voltage and limit current to approximately the pre-fault level,
3. Very slow - isolator - a device which waits for system controls to depress the dc voltage and reduce current to near-zero.

It is believed that there are two "near-term" (no date appended) applications for dc breakers, and that these applications should form the basis for the systems to be investigated:

1. Parallel line switching, as per the Nelson River System. Duties are not severe in this application, and a dc breaker would need to develop only a modest counter-voltage. This could be a fairly near-term application; presently slower air-break isolation switches are to be used for current transfer between bipoles.
2. Multiterminal HVDC systems in an interconnected ac system. The western portion of the U.S. has the potential of as many as seven dc terminals. Some manner of dc breaker would clearly be required for interconnection of these terminals.

AREAS OF INVESTIGATION

The following topics could form the basis for a statement or work:

1. System Definition

The specific systems to be investigated (ac and dc) are to be identified. All data on both the ac and the dc systems are to be collected. It is suggested that the West Coast system would best serve as the study example, especially in anticipation of the testing of a prototype dc breaker at Celilo. Further, both of the "application modes" just referred to can be achieved by appropriate reconnection of the Pacific Intertie accompanied by control modifications.

2. Transient Performance Criteria

The transient response of the existing ac system is to be evaluated, and criteria for stability are to be established. These studies would be conducted both with and without the existing Pacific HVDC Intertie.

3. Breaker-related Electrical Transients

Develop the digital model for the study of electrical transients in a dc system including dc breakers. This will be applicable in two areas:

- a. DC breaker design and operation for use with the Western System,
- b. Transient associated with the design and field testing of the prototype dc breaker.

4. Transient Stability

Studies will examine the relationships between breaker design and operating parameters (including speed) and ac system parameters (especially transient stability). Topics here include normal operating modes, contingencies, control philosophy, dynamic operation (modulation), parallel line switching, fault performance, failure modes, backup protection. System-specific data is to be collected relating system stability, dc breaker/control time response, and system and dc breaker energies.

STUDY TOOLS/AVAILABLE PERSONNEL

Two principal study tools are recommended:

- a. The Bonneville Transient Stability Program as augmented to include multiterminal HVDC systems and dc breakers. This program is sufficiently developed to make unnecessary the expenditure of resources for new program development. Some additional modeling features would need to be incorporated (e.g., new control philosophies for multiterminal dc systems).
- b. The Bonneville Electromagnetic Transients Program (EMTP). This program is likewise sufficiently developed such that minimal modification is needed. Some effort will be required in developing multiterminal dc source models and dc circuit breaker models.

Additional studies, if required, could be conducted on an HVDC System Simulator provided that adequate ac system representation is available.

Personnel needs fall in three categories of expertise.

- AC system configuration and transient stability.
- DC system configuration and control methodology.
- DC circuit breaker configuration and operation.

Appropriate personnel can be identified at Bonneville, the University of Wisconsin, General Electric, and several consulting firms in this country and Canada. The availability of these persons is by no means assured.

RECOMMENDATIONS

The following steps are recommended:

1. The overall scope of the study is approved.
2. A team of preliminary investigators is established.
3. A detailed statement of work is prepared.
4. Appropriate tools and personnel are identified.
5. A contractual commitment is reached.
6. The study is conducted.

REFERENCES

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5. Panel Session on "Requirements for Multiterminal HVDC Transmission," presented at IEEE PES Winter Power Meeting, February, 1980. Authors included R. Harrison, G. Breuer, J. Vithayathil, S. Svensson, P. Lips, J. Bowles.

WORK STATEMENT FOR THIS QUARTER

All requirements of this contract have been complied with to date. Dr. Long has been devoting about 30 percent of his time to this contract, and is continuing the services of a graduate student. Travel expenditures are slightly above projections in the contract. No computer simulation has yet been initiated.