NRC Research and/or Technical Assistance Rept

PDR

EGG-EA-5721

May 1982

PROPOSED DRAFT BRANCH TECHNICAL POSITION PSB-3

LICENSING GUIDANCE FOR ENHANCING THE RELIABILITY OF THE DC POWER SYSTEM

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This is an informal report intended for use as a preliminary or working document

Prepared for the
U.S. Nuclear Regulatory Commission
Under DOE Contract No. DE-AC07-76ID01570
FIN No. A6463

EG&G idaho

EG&G Idaho, Inc.

FORM EG&G-398
(Rev. 03-82)

INTERIM REPORT

Accession No. ______________

Report No. EGG-EA-5721

Contract Program or Project Title:

Development of Licensing Guidelines for DC Power Systems Reliability (A30)

Subject of this Document:

Proposed Draft Branch Technical Position PSB-3, Licensing Guidance for Enhancing the Reliability of the DC Power System

Type of Document:

Technical Evaluation Report

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Date of Document:

May 1982

Responsible NRC Individual and NRC Office or Division:

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Prepared for the
U.S. Nuclear Regulatory Commission
Washington, D.C.
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LICENSING GUIDANCE FOR ENHANCING THE RELIABILITY OF THE DC POWER SYSTEM

May 1982

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ABSTRACT

This report is a position for the enhancement of the reliability of safety-related DC power systems at nuclear power stations. This position was developed by evaluating the recommendations of NUREG-0666, other Nuclear Regulatory Commission recommendations and industry standards.

FOREWORD

This report is supplied as part of the topic "Development of Licensing Guidelines for DC Power Systems Reliability (A30)," being conducted for the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Division of Systems Integration by EG&G Idaho, Inc., Reliability and Statistics Branch.

The U.S. Nuclear Regulatory Commission funded the work under the authorization B&R 29-19-50-52-3, FIN No. A6463.

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PROPOSED DRAFT BRANCH TECHNICAL POSITION PSB-3
LICENSING GUIDANCE FOR ENHANCING THE RELIABILITY
OF THE DC POWER SYSTEM

A. BACKGROUND

The DC power system in a nuclear power plant provides control and motive power to valves, instrumentation, emergency diesel generators, and many other components and systems during all phases of plant operation including abnormal shutdowns and accident situations.

The adequacy of safety related DC power supplies was questioned by a nuclear consultant in a letter to the Advisory Committee on Reactor Safeguards in April 1977. A specific area of concern was the adequacy of the minimum design requirements for DC power systems, particularly with regard to multiple and common cause failures. This concern related to the application of the single failure criterion for assuring a reliable DC power supply which may be required for the functionability of shutdown cooling systems.

The NRC staff reviewed the adequacy of safety related DC power supplies at operating nuclear power plants. The staff reviewed typical designs, operating experience, and decay heat removal capability with DC power system failure. A preliminary assessment of accident scenario probabilities was made using the results of the "Reactor Safety Study" NRC Report WASH-1400, NTIS, October 1975. The results of the initial staff assessment of the safety significance of this issue was reported in NUREG-0305, "Technical Report on DC Power Supplies at Nuclear Power Plants," dated July 1977. In that report, it was concluded that the failure of the DC power supplies represented a small contribution to the probability of a core melt accident; however, performance of a quantitative reliability assessment of the DC power systems was recommended to add confidence to that judgment, and to identify and provide a basis for any changes in licensing criteria that may be deemed necessary.

Accordingly, the adequacy of safety related DC system power supplies was identified as a generic safety task (designated A-30) and a task action plan was developed and a study initiated. The results of this study are documented in NUREG-0666, "A Probabilistic Safety Analysis of DC Power Supply Requirements for Nuclear Power Plants," April 1981.

The conservatisms inherent to the approach used in NUREG-0666 generally confirm the earlier assessment reported in NUREG-0305. However, NUREG-0666 provides recommendations, and supporting technical bases for augmenting the minimum design criteria and procedural requirements which will provide greater assurance of DC power supply reliability. These recommendations for augmenting the minimum requirements for DC power systems are: (1) prohibiting certain design and operational features of the DC power systems, such as use of a bus tie breaker, which could compromise division independence; (2) augmenting the test and maintenance activities presently required for battery operability to also include preventive maintenance on bus connections, procedures to demonstrate DC power availability from the battery to the bus, and administrative controls to reduce the likelihood of battery damage during testing, maintenance, and charging activities; and (3) requiring staggered test and maintenance activities to minimize the potential for human error-related common cause failure associated with these operations. In addition, a fourth recommendation, for assuring that a DC power supply failure does not present an unacceptable additional risk of core melt, was developed as follows; (4) requiring design and operational features that are adequate to maintain reactor core cooling in the hot standby condition following the loss of any one DC power bus and a single independent failure in any other system required for shutdown cooling.

As a result of a review of an event at Zion Unit 2, which involved the loss of a safety related DC bus leading to a loss of control power to certain 4kV AC buses, to all main control room annunciators, and to various other loads, it was concluded that sufficient operational status information on safety related DC systems may not be provided in the control room of all operating reactor facilities. As a corollary it was suggested that more attention should be given to the design and review of the annunciation systems of nuclear power stations.

A multi-unit action was proposed to require licensees of operating reactors to review their design and to propose revisions, as necessary, to ensure that:

a) The plant annunciators and monitoring systems, pertaining to the status of all DC buses in the plant, are available to the control room operator at all times; and

b) The plant bypass status indication system monitors the position of the station battery output breaker or fused disconnect switch (if provided) and the charger input and output breakers.

This multi-unit action was never initiated; it was held in abeyance for the completion of generic safety task A-30. To enhance the reliability of the DC system, the concerns of this multi-unit action as well as the recommendations of NUREG-0666 are included in the following Branch Technical Position:

B. BRANCH TECHNICAL POSITION PSB-3

1. Electrical interconnections between redundant divisions of the Class 1E DC power system, if provided, shall meet the following positions.

   a) The interconnections shall only be accomplished by manual means that have features to facilitate administrative control.

   b) The use of the interconnections shall be restricted by technical specifications to when the unit is in either the cold shutdown or the refueling mode of operation. The means of accomplishing the interconnections shall be by strict administrative control.

c) The design of each interconnection shall prevent a single failure or inadvertent closure of one interconnecting device from compromising division independence. An acceptable design includes a minimum of two series connected disconnect devices that are physically separated, administratively kept normally open, and annunciated in the control room upon closure.

d) Where interconnections exist between Class 1E DC power systems of separate units at a multi-unit station, the technical specifications shall include surveillance requirements on the interconnecting devices and limiting conditions of operation on the use of the interconnections.

2. The DC system shall be monitored to the extent needed to show that it is ready to perform its intended function when required. As a minimum, the following abnormal conditions shall be alarmed in the control room: (1) battery circuit open, (2) battery charger circuit open, (3) DC system ground fault, (4) DC bus undervoltage, (5) DC overvoltage, (6) battery charger failure, and (7) battery discharge. In addition, the following parameters shall be monitored: (1) DC bus voltage, (2) battery circuit input current, (3) battery circuit output current, and (4) battery charger output current. A failure of one DC system shall not cause total loss of the control room annunciator system.

3. Circuit breakers or other devices that may be used to disconnect the battery or battery charger from the DC bus or the battery charger from its AC power source during maintenance or testing shall provide input to the bypassed and inoperable status indication for plant safety systems.

4. Adequate written procedures and administrative controls shall be implemented for maintenance, testing, and operational activities performed on each station battery and associated distribution system in order to minimize the likelihood of accidental damage to the DC system. These procedures and controls shall include but not be limited to the following:

   a) Procedures that prevent maintenance or testing activities occurring on redundant DC divisions at the same time. All test and maintenance procedures and activities should be reviewed in order to minimize the potential for human error causing more than one DC division to be unavailable.

   b) Procedures that assure maintenance or test activities are done correctly. Considerations should be included such as rotation of qualified personnel for test and maintenance activities to the extent practical and systematic verifications of completed work by other qualified personnel.

5. The technical specifications shall include limiting conditions of operation for each of the following requirements.

   a) At least once per seven (7) days, verify pilot cell electrolyte level, pilot cell specific gravity or charging current, pilot cell float voltage, total battery terminal voltage on float charge, and physical conditions.

   b) At least once per 92 days, or within seven (7) days after a battery discharge, overcharge, or if a pilot cell is outside of its seven (7) day surveillance requirement, verify electrolyte level of each cell, average specific gravity of all cells, specific gravity of each cell, average electrolyte temperature, float voltage of each cell, and visual inspection or measure resistance of terminals and connectors including connectors between the battery and the DC bus.

   c) At least once per 18 months, verify resistance of each connection, physical condition of the battery, each battery charger's capability to deliver rated ampere output to the DC bus, and the capability of the battery to deliver its design duty cycle to the DC bus (service test).

   d) At least once per 60 months, verify capacity of each battery by a performance discharge test. If the battery shows signs of degradation or has reached 85% of the service life expected for the application, verify capacity annually by a performance discharge test. Degradation is indicated when the battery capacity drops more than 10% of rated capacity from its average on previous performance tests, or is below 90% of the manufacturer's rating.

6. Plant design and operational features shall be such that following the loss of one DC power supply or bus: (a) redundant capability is maintained for ensuring continued and adequate reactor core cooling; (b) RCS integrity and isolation capability are maintained; and (c) operating procedures, instrumentation, and control functions are adequate to initiate systems as required to maintain adequate core cooling. In essence, reactor core cooling capability shall be maintained irregardless of reactor trip following the loss of any one DC power supply or bus and a single independent active failure in any other system required for shutdown cooling.

The following considerations and assumptions should be used to determine the adequacy of design and operational features:

a) DC power bus losses ranging from momentary to several hours duration should be considered. A limit may be placed on the DC power bus duration outage where a comprehensive analysis (FMEA) has been performed using reasonable assumptions including credible failures (human and hardware related) and an evaluation of the repair actions and time necessary to complete restoration, or perform an equivalent evaluation.

b) The transient conditions and interactions caused by the DC power bus loss and individual single failures which may affect the ability to maintain adequate reactor core cooling should be considered.

c) Systems and components which become unavailable or attain an undesired operating state due to DC power bus loss should be considered unavailable and should not be considered as single independent failures.

d) Single failures affecting the availability of DC power supplies in addition to the initial DC power bus loss need not be considered for those DC power systems or subsystems in which positions 1, 4, and 5 above have been satisfied.

e) Systems and components available to accomplish shutdown cooling should be (1) safety grade, or (2) used regularly during plant operation, or (3) subject to routine operability checks.

f) Single failures should be interpreted to mean single active failures except where further clarification is provided in one of the above "considerations."