TAP A-44

STATION BLACKOUT

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Applicability:	All BWR and PWR
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1. DESCRIPTION OF PROBLEM

A. Statement of Issue

The complete loss of AC electrical power to the essential and non-essential switchgear buses in a nuclear power plant is referred to as a "Station Blackout." Because many safety systems required for reactor core decay heat removal are dependent on AC power, the consequences of a station blackout could be a severe core damage accident. Therefore, the technical issue is (a) whether the probability of a station blackout may be too high, and (b) what the consequences of a station blackout are; that is, whether severe core damage may result.

B. Background

The issue of Station Blackout arose because of the historical experience regarding the reliability of AC power supplies. A number of operating plants have experienced a total loss of offsite electrical power, and more occurrences are expected in the future. During each of these loss of offsite power events, the onsite emergency AC power supplies were available to supply the power needed by vital safety equipment. However, in some instances, one of the redundant emergency power supplies has been unavailable. In addition, there have been numerous reports of emergency diesel generators failing to start and run in operating plants.

The results of the Reactor Safety Study[1] showed that for one of the two plants evaluated, a station blackout accident could be an important contributor to the total risk from nuclear power plant accidents. Although this total risk was found to be small, the relative importance of station blackout accidents was established. This finding and the historical diesel generator failure experience raised the concern about Station Blackout to an unresolved safety issue.

C. Purpose

The purpose of this Task is to evaluate the adequacy of current licensing design requirements to assure that nuclear power plants do not pose an unacceptable risk of a station blackout accident.

The NRC safety design requirements applicable to station blackout can be grouped into three categories:

1. reliability of the offsite AC power supplies;
2. reliability of the emergency AC power supplies; and
3. capability of plants to remove decay heat with AC power supplies unavailable.

Appendix A to 10 CFR 50 defines a total loss of offsite power as an anticipated occurrence (Category 1 above). As such, it is required that an independent emergency onsite AC power supply be provided at nuclear plants. It is further required by NRC safety criteria that electric power for safety systems at nuclear plants be supplied by at least two redundant and independent divisions (Categories 1 and 2). Each electrical division for safety systems includes an offsite AC power connection, an onsite emergency AC power supply (usually a diesel generator), and DC power sources. Those safety systems required to remove decay heat from the reactor core following shutdown are required to have available these diverse AC power supplies. Surveillance requirements include periodic testing for emergency diesel generators (Category 2) and other related electrical equipment. Additional rec' rements are that diverse power drives and supporting systems independent of AC power must be provided for one emergency feedwater train in PWRs (Category 3). The design practice for BWRs is to include at least one decay heat removal system (e.g., Reactor Core Isolation Cooling) driven by a source independent of AC power (Category 3).

2. PLAN FOR PROBLEM RESOLUTION

A. Approach

Technical analyses in all three of the above categories are planned for this task. However, the principal focus will be on category 2, reliability of emergency AC power supply. This is justified by several considerations. First, the questions raised about category 2 were basically responsible for identification of Station Blackout as a safety issue. Second, if safety improvements are required, it will be easier to analyze and identify them and implement them in category 2 rather than in categories 1 and 3. For example, offsite power reliability (category 1) is dependent on a number of factors which are difficult to analyze and to control, such as regional electrical grid stability, weather phenomena, local industrial and population growth, and repair and restoration capability. Also, the capability of a plant to withstand a station blackout (category 3) would require many decay heat removal-related systems, components, instruments and controls to be independent of AC power. These will vary from plant to plant, requiring considerable effort to analyze all of them and to assure that the plants indeed have that capability. Third, some progress has been made in category 3. A significant improvement is underway for all operating PWRs by backfitting the auxiliary feedwater system to make it independent of AC power. Thus, the reliability of emergency AC power supplies is of principal importance to this task.

During the development of this task action plan, a preliminary screening analysis was begun to identify plants most likely to suffer core damage due to a loss of all A.C. power supplies. The intent of this work was to survey the frequency and implication of station blackout accidents in operating plants and identify any especially high risk plants which might require further analysis or action on an urgent basis. Initial results showed no such plants. Completion of this task is the first step in resolving this issue.

A more detailed evaluation of station blackout concerns will follow the completion of the preliminary analysis. It is recognized that this issue is centered around a concern for the adequacy of A.C. power supply reliability, especially for emergency onsite AC power supplies. As such, this area will comprise the major program effort to resolve this issue. Typical offsite and emergency A.C. power supplies will be evaluated including a review of past operating (failure) experience. This effort is limited to power supply availability and will not include an evaluation of power distribution network adequacy or power capacity requirements.

In order to provide a consequence perspective, tasks to evaluate station blackout accident sequences and associated plant response analyses are included. The Interim Reliability Evaluation Program (IREP), which will be carried out concurrently with this program, will be used as a primary information source in developing the shutdown cooling reliability models and accident scenarios needed to perform these tasks.

Upon completion of the technical evaluation tasks, a regulatory position will be developed for review and comment. A NUREG report documenting the technical studies of this program and final regulatory position will be published.

B. Management of Work

The responsibility for carrying out a program to resolve this issue was transferred to RES by memorandum dated July 13, 1979, from the Director of NRR to the Director of RES. The Probabilistic Analysis Staff of RES will provide the program management; however, NRR will remain cognizant through assignment of liaison personnel and participation in subtasks as identified in this TAP. In addition, NRR has the responsibility of obtaining and providing to the task manager operating experience information required from licensees as identified in this plan. NRR also has the responsibility of taking licensing related actions on station blackout issues during the conduct of this program.

C. Tasks

1. Preliminary Screening Analysis of Operating Plants

   A probabilistic safety assessment will be performed and documented to provide a preliminary evaluation of station blackout accident sequences at operating nuclear power plants. The purpose of this work will be to effectuate a screening analysis to identify any plants of unusually high susceptibility to station blackout and subsequent core damage. As may be necessary, safety improvements in design and operation will be identified.

2. A.C. Power Supply Reliability Evaluation

Failure modes and reliability analyses will be performed for typical offsite and emergency A.C. power supplies. These analyses will include an indepth examination of the potential causes, frequency, and duration relationships for station blackouts. The A.C. power supply reliability subtasks will include:

2.1 A.C. power supply design review--Typical offsite and emergency A.C. power supply configurations will be identified and generically grouped. Consideration will be given to type of power source, line diagrams showing redundancy and switching, plant systems supplied by each bus/division, AC power dependence on DC power, and operational characteristics.

2.2 A.C. power supply operating experience review--The operational experience regarding loss of offsite power and emergency A.C. power supplies (particularly diesel generators) will be reviewed. This will include the identification of data needs and the collection of the information. Knowledge gained from previous studies of offsite and emergency AC power supply reliability will be included. The intent of this task is to obtain enough operational experience information to allow the construction of meaningful reliability models with due consideration to the limitations of such models.

2.3 Reliability of A.C. power supplies--A reliability analysis of the typical A.C. power supply configurations will be performed. Both offsite and onsite power supplies will be modeled with special consideration given to interactive and common cause failure modes, including those induced by human error. The effect of regional and local factors on the loss and recovery of A.C. power will be considered where possible. Aspects of design and operation which have the potential to improve A.C. power supply reliability will be identified and the amount of improvement will be estimated. Design and operational recommendations to assure AC power supply reliability will be developed.

3. Accident Sequence Analysis

An investigation into the probability and consequence of station blackout accidents will be conducted through both generic and plant specific studies. The insights gained from the IREP will be used to enhance the limited detail of the generic evaluations. These studies will include the reliability of shutdown cooling systems given a loss of A.C. power supplies, an evaluation of the hazards posed by extended blackouts, and reactor coolant inventory requirements during station blackouts. These considerations will be coupled with the results of Task 2 to identify a generic set of dominant station blackout accident scenarios. The subtasks for this evaluation will include:

3.1 Accident sequence review--Event and fault tree analyses will be reviewed to identify dominant station blackout sequences, failure modes, and consequences. These will include the Crystal River 3 analyses and, if available, the first six plant group of IREP. This information will supplement that currently available from the Reactor Safety Study[1] and follow-on studies.

3.2 Shutdown cooling reliability--A generic review of systems and components used for shutdown cooling will be performed to identify A.C. power dependencies and requirements, adequacy of A.C. independent systems, and the reliability of these systems during a station blackout. The system reliability results obtained from accident sequence reviews will be factored into this subtask.

3.3 Generic accident sequence evaluation--A set of generic event trees will be developed and the dominant station blackout accident scenarios will be characterized. The probability and consequence of these scenarios will be used to provide a simplified risk perspective. This information will be used to establish acceptable requirements for AC power supply reliability and decay heat removal capability for station blackout.

4. Plant Response to Station Blackout

Reactor coolant system response analyses will be performed for station blackout accident scenarios. Typical NSSS designs (at least one for each LWR vendor) will be analyzed to provide an estimate of the core damage times and to determine the important operational characteristics associated with these accidents. The subtasks for this work are:

4.1 Develop plant response models--Generic and plant specific response characteristics will be considered in the development of analysis models for each LWR vendor. A preliminary and simplified event tree and accident scenario list will be used to determine the modeling requirements. Models will be best estimate where possible using existing computer codes.

4.2 Analysis matrix--An initial accident analysis matrix will be developed from simplified event trees. The accident sequence evaluations of Task 3 and initial accident sequence analysis results will be used to revise the accident analyses matrix into a final set of plant response analyses which will provide a characterization of reactor thermal response for station blackout accidents.

4.3 Plant response analyses--Analyses will be performed for each LWR vendor NSSS to assess the time dependence and consequences of station blackout accident sequences; i.e., mitigation by adequate core cooling or damage to the core and possible melting. These results will be reviewed to identify important system or component availability and operational characteristics, including operator actions.

5. Licensing Requirements

The results of Tasks 1-4 will be used to develop any licensing requirements which may be needed to resolve this issue. Upon completion of Tasks 2-4, a recommended revision or reaffirmation of current licensing requirements will be provided. The development of a draft NUREG covering the conduct and conclusions of this program and appropriate internal and public review of the draft report are included in this task.

D. Schedule

The following schedule has been developed for the completion of the major tasks of this program:

1. Interim Study

Draft report	August 1980
Final report	October 1980

2. AC Power Reliability

Power supply design review	February 1981
Operating experience evaluation	August 1981
Reliability evaluation	December 1981

3. Accident Sequence Analysis

IREP review	April 1981
Shutdown cooling reliability	August 1981
Accident sequence evaluation	January 1982

4. Plant Response to Station Blackout

Plant response models	December 1980
Analysis matrix	February 1981
Plant response analyses	June 1981

5. Licensing Position

Internal-Peer Review	March 1982
Draft position (draft NUREG)	May 1982
Final position (NUREG approved)	October 1982

3. BASIS FOR CONTINUED PLANT OPERATION AND LICENSING PENDING COMPLETION OF TASK

As stated in Section 1, the purpose of this task is to evaluate the adequacy of current licensing design requirements regarding the risk of a station blackout accident resulting in unacceptable core damage. In particular, the adequacy of emergency AC power supplies reliability has been questioned. The current licensing criteria require licensees to provide redundant emergency AC power supplies, to demonstrate emergency AC power supply reliability (R.G. 1.108), and to include the capability of removing decay heat using at least one shutdown cooling train independent of AC power.

In the event of a total loss of AC power at PWRs, the auxiliary feedwater (AFW) system can provide a heat sink via the steam generators to remove the core decay heat. Since the TMI-2 accident and subsequent studies further highlighted the importance of the AFW systems, the Bulletins and Orders Task Force[2] performed a review of these systems for operating Combustion Engineering and Westinghouse designed PWRs. The objectives of this study were to: (1) identify necessary changes in AFW system design or related procedures to assure continued safe operation, and (2) to identify other system characteristics in the AFW system design of these plants which, on a long term basis, may require system modification. Based on this study, the Bulletins and Orders Task Force made a number of recommendations to improve the reliability of the AFW systems. Some of these recommendations were specifically made to cover the concern for the total loss of offsite and onsite AC power. For the near term, the Bulletins and Orders Task Force required that as-built plants be capable of providing the required AFW flow for at least 2 hours from one AFW pump train independent of any AC power source. For the long term, it is required that this function be performed automatically in addition to various other improvements. The near term recommendation has been met for most CE and Westinghouse PWRs; the long term improvements are scheduled to be completed by January 1, 1982.

The reliability of the AFW systems for the Babcock and Wilcox operating PWRs was reviewed as part of the May 1979 shutdowns for these plants. This review resulted in various short-term system and emergency procedure modifications to improve the availability of these systems. A more systematic reliability review of these plants is now in progress. These plants will also be required to meet the long term requirements discussed above.

Boiling water reactors contain various systems to remove core decay heat following the total loss of AC power. These systems include the isolation condensers on BWR/1 through BWR/3 plants and the steam driven high pressure coolant injection (HPCI) and reactor core isolation cooling (RCIC) system. For BWR/1, BWR/2 and early BWR/3 plants, the isolation condenser will provide an adequate heat sink for a minimum of 40 minutes. For other BWRs, adequate cooling can be maintained for approximately 2 hours. The Bulletins and Orders Task Force did not require any specific improvements for these systems following its review; however, a review of BWRs is included in this study.

In addition to the above, a preliminary study of operating plants was performed to assess plant vulnerability using probabilistic techniques. This study did not identify any plants of unusually high susceptibility to a severe core damage accident resulting from a station blackout. Accordingly, it is concluded that plants may continue to be licensed and operated while the preliminary evaluation (Task 1) is completed. After completion of the preliminary evaluation, any additional interim licensing requirements will be identified.

4. ASSISTANCE FROM OTHER RES DIVISIONS

The Division of Reactor Safety Research (RSR) will provide assistance in developing reactor coolant system response characteristics identified in Task 4. The Probabilistic Analysis Staff will provide direction to RSR on appropriate accident scenarios to be analyzed. Funding and program management of contractor efforts in this area will also be provided by RSR.

5. ASSISTANCE REQUIRED FROM NRR

A. Division of Licensing. Provides the coordination necessary to expedite the collection of required operating reactor experience and design data. Information needs will be related to the reliability assessments for offsite power, emergency AC power (primarily emergency diesel generators), and shutdown cooling systems. DL will also contribute to the formulation, review and approval of interim and final licensing positions.

Manpower requirements

Operating Reactors Branch No. 1	0.05	my
Operating Reactors Branch No. 2	0.20*	my
Operating Reactors Branch No. 3	0.05	my
Operating Reactors Branch No. 4	0.05	my

*reflects NRR lead reviewer activity

B. Division of Systems Interaction. Provides review and comment on the technical evaluations provided by the Task Manager in the areas of instrumentation and control, electrical and power systems, reactor and auxiliary systems, and systems interactions. DSI will provide assistance in the identification of design and operational characteristics of AC power supplies and systems required for shutdown cooling. In addition, DSI will contribute to the formulation, review, and approval of interim and final licensing positions.

Manpower requirements

Instrumentation and Control Systems Branch	0.05	my
Power Systems Branch	0.10*	my
Reactor Systems Branch	0.05	my
Auxiliary Systems Branch	0.05	my
Systems Interaction Branch	0.05	my

*reflects PSB responsibility directly related to station blackout

C. Division of Human Factors. Provides review and comment on those technical evaluations involving man/machine interfaces. In this area, DHF will contribute to the formulation, review, and approval of interim and final licensing positions.

Manpower requirements

Human Factors Engineering Branch	0.05	my
Procedures and Test Review Branch	0.05	my

D. Division of Safety Technology. Provides liaison between NRR and PAS, and provides general assistance in the coordination of activities performed within NRR which are part of this Task Action Plan. DST has primary responsibility for the initial review of draft licensing recommendations and for coordination of the internal management and public review process required to adopt the final licensing positions. DST will also coordinate the formal revision and publication of licensing documents (i.e., regulatory guides, standard review plan, etc.) with the Office of Standards Development.

Manpower requirements

Generic Issues Branch	0.20*	my
Licensing Guidance Branch	0.05	my
Reliability and Risk Assessment Branch	0.05	my

*reflects GIB overall coordination responsibility

6. TECHNICAL ASSISTANCE

Direct technical assistance to the program will be required for Tasks 2 and 3. Funding will be provided by the Office of Nuclear Reactor Regulation. Technical assistance requirements for Task 4 will be developed and funded directly by the Division of Reactor Safety Research, RES. The following is a brief description of the technical assistance required for Tasks 2 and 3 for this program.

A. Offsite Power Reliability

1. Contractor - to be selected.

2. NRC managing organization - PAS (RES).

3. Scope - Identify initiating events which can cause a loss of offsite power, evaluate the expected frequency, and determine dominant factors affecting the reliability of

offsite power supplies and the recovery of offsite power. This will include consideraion of power supply and circuit configurations, operational characteristics (technical specifications, limiting conditions of operation, operating procedures, human interactions), and location dependent factors (multiple unit sites, proximity to alternate power supplies, regional grid reliability). In the context of these considerations, operating experience data will be evaluated, reliability models will be developed, and reliability estimates will be provided. Features which may improve the reliability of offsite power supplies will also be evaluated.

4. Funding requirements - $150K.

B. Emergency A.C. Power Reliability

1. Contractor - to be selected.

2. NRC managing organization - PAS (RES).

3. Scope - Identify range of emergency A.C. power supply design configurations used at nuclear power plants. Collect and analyze operating experience data. Quantify probabilities of dominant emergency power supply failure modes. Review experience at several operating nuclear plants. Review emergency power supply reliability experience from other applications such as DOD and FAA. Develop

predictive reliability models for emergency A.C. power supplies including component and design differences, operational characteristics, and power supply recovery from failure. Identify practical reliability improvements and quantitative reliability goals. Earlier NRR qualitative studies and other studies will be reviewed and incorporated. Estimate reliability increases possible and associated costs.

4. Funding requirements - $300K.

C. Station Blackout Accident Sequence Evaluation

1. Contractor - to be selected.

2. NRC managing organization - PAS (RES).

3. Scope - Develop generic event trees, characterize dominant accident scenarios, and provide a risk/consequence perspective for station blackout accidents. A review of IREP accident sequences and shutdown cooling systems reliability associated with a station blackout will be conducted to supplement the generic evaluations. The results of the offsite and emergency A.C. power supply reliability studies will be used in conjunction with the generic accident sequence and shutdown cooling reliability assessment to provide station blackout accident perspectives.

4. Funding requirements - $150K.

7. INTERACTIONS WITH OUTSIDE ORGANIZATIONS

Interaction with outside organizations could include EPRI, NSAC, INPO, FERC, FAA, utilities, NSSS vendors, A&Es, and emergency diesel generator manufacturers. Peer review will be conducted through ACRS briefings and by the establishment of a peer review panel selected from outside NRC having appropriate expertise.

8. POTENTIAL PROBLEMS

The potential problem areas which have been identified are provided below:

A. Program funding must be approved and obtained. If competitive contractor bidding is necessary, the program will be delayed by approximately one year.

B. Identification of reliability goals and translation of probabilistic results into licensing requirements.

C. Obtaining necessary operating experience on AC power supplies.

D. Uncertainty in what information will be available from IREP and on what schedule.

E. Liaison needed between NRR and RES.

REFERENCES

1. U.S. Nuclear Regulatory Commission, "Reactor Safety Study," NRC Report WASH-1400, NTIS, October 1975.

2. NUREG-0645, "Report of the Bulletins and Orders Task Force," January 1980.