

March 30, 2016

MEMORANDUM TO: John W. Lubinski, Acting Deputy Director  
for Engineering  
Office of Nuclear Reactor Regulation

FROM: Lawrence E. Kokajko, Director **/RA/**  
Division of Policy and Rulemaking  
Office of Nuclear Reactor Regulation

SUBJECT: EVALUATION FOR COMPLIANCE BACKFIT EXCEPTION: OPEN  
PHASE CONDITION DESIGN VULNERABILITY IN ELECTRIC  
POWER SYSTEM

The NRC staff prepared a documented evaluation of the compliance backfit exception for the open phase condition design vulnerability that was the subject of Bulletin 2012-01, "Design Vulnerability in Electric Power System." This evaluation supports changing the current licensing basis for operating nuclear reactors to require that the electric power system meet in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," General Design Criterion 17, "Electric Power Systems," or the principal design criteria specified in the final safety analysis report assuming all potential open phase conditions in offsite power. The enclosed documented evaluation provides the basis that this proposed backfit falls within the compliance exception in 10 CFR 50.109(a)(4)(i).

Enclosure:  
As stated

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## **EVALUATION FOR COMPLIANCE BACKFIT EXCEPTION: OPEN PHASE CONDITION DESIGN VULNERABILITY IN ELECTRIC POWER SYSTEM**

### **I. INTRODUCTION**

Operating experience has identified an unrecognized design vulnerability involving certain offsite power open phase conditions (OPCs) that was not considered by the NRC staff in past NRC approvals of the design of the electric power system. The electric power system design requirements for nuclear power plants are provided in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," General Design Criterion (GDC) 17, "Electric Power Systems," or the principal design criteria specified in the final safety analysis report (FSAR). This compliance backfit exception documented evaluation supports changing the current licensing basis for operating nuclear reactors to require that the electric power system meet GDC 17 or the principal design criteria in the FSAR assuming all potential open phase conditions in offsite power. This documented evaluation provides the basis that this proposed backfit falls within the compliance backfit exception in 10 CFR 50.109(a)(4)(i).

### **II. BACKGROUND**

Backfitting is defined at 10 CFR 50.109(a)(1) as: [T]he modification of or addition to systems, structures, components, or design of a facility; or the design approval or manufacturing license for a facility; or the procedures or organization required to design, construct or operate a facility; any of which may result from a new or amended provision in the Commission's regulations or the imposition of a regulatory staff position interpreting the Commission's regulations that is either new or different from a previously applicable staff position. . . . 10 CFR 50.109(a)(4)(i) provides that a backfit analysis need not be prepared to support an NRC backfitting action if a documented evaluation demonstrates that the modification constituting backfitting is "necessary to bring a facility into compliance with a license or the rules or orders of the Commission, or into conformance with the written commitments by the licensee...."

The Commission shed additional light on how the compliance exception should be interpreted in the Supplementary Information published with its 1985 final backfitting rule:

The compliance exception is intended to address situations in which the licensee has failed to meet known and established standards of the Commission because of omission or mistake of fact. It should be noted that new or modified interpretations of what constitutes compliance would not fall within the exception and would require a backfit analysis and application of the standard.<sup>1</sup>

The NRC evaluation of compliance backfit exception for the open phase condition design vulnerability in the electric power system is provided below. Note that the phrases "known and established standards" and "Omitted Fact" used below pertain to the above 1985 Supplementary Information.

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<sup>1</sup> Revisions of Backfitting Process for Power Reactors, 50 Fed. Reg. 38,097, 38,103 (September 20, 1985) (codified at 10 CFR Parts 2 and 50).

### III. EVALUATION

#### (1) The “known and established standards” at issue;

##### General Design Criteria (GDC) Plants

Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Appendix A, “General Design Criteria for Nuclear Power Plants,” applies to currently operating plants with construction permits issued after May 21, 1971. The Introduction states, in part, that

Under the provisions of § 50.34, an application for a construction permit must include the principal design criteria for a proposed facility. The principal design criteria establish the necessary design, fabrication, construction, testing, and performance requirements for structures, systems, and components important to safety; that is, structures, systems, and components that provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public.

These GDC establish minimum requirements for the principal design criteria for water-cooled nuclear power plants similar in design and location to plants for which construction permits have been issued by the Commission. The GDC are also considered to be generally applicable to other types of nuclear power units and are intended to provide guidance in establishing the principal design criteria for such other units.

General Design Criterion 17, “Electric Power Systems,” states in part

An onsite electric power system and an offsite electric power system shall be provided to permit functioning of structures, systems, and components important to safety. The safety function for each system (assuming the other system is not functioning) shall be to provide sufficient capacity and capability to assure that (1) specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded as a result of anticipated operational occurrences, and (2) the core is cooled and containment integrity and other vital functions are maintained in the event of postulated accidents....

....

Electric power from the transmission network to the onsite electric distribution system shall be supplied by two physically independent circuits (not necessarily on separate rights of way) designed and located so as to minimize to the extent practical the likelihood of their simultaneous failure under operating and postulated accident and environmental conditions....

Provisions shall be included to minimize the probability of losing electric power from any of the remaining supplies as a result of, or coincident with, the loss of power generated by the nuclear power unit, the loss of power from the transmission network, or the loss of power from the onsite electric power supplies.

## Pre-GDC Plants

For current operating nuclear power plants with construction permits issued before the promulgation of 10 CFR Part 50, Appendix A, on May 21, 1971<sup>2</sup>, the principal design criteria specified in the plant Updated Final Safety Analysis Report (UFSAR) sets forth criteria similar to GDC 17 which requires, among other things, that plants have an offsite and an onsite electric power system with adequate capacity and capability to ensure the functioning of SSCs important to safety in the event of anticipated operational occurrences and postulated accidents.

The following electrical design criteria were used for licensing of nuclear power plants by Atomic Energy Commission (AEC). They represent the Atomic Industrial Forum (AIF) version of proposed criteria issued by the AEC for public comments. The specific criteria specified in the plant UFSAR for electric power system requirements are:

### AIF- Criterion 21

Sufficient normal and emergency sources of electrical power must be provided to assure a capability for prompt shutdown and continued maintenance of the reactor facility in a safe condition under all credible circumstances.

### AIF- Criterion 24

In the event of loss of all offsite power, sufficient alternate sources of power shall be provided to permit the required functioning of the protection systems.

### AIF- Criterion 39

An emergency power source shall be provided and designed with adequate independency, redundancy, capacity, and testability to permit the functioning of the engineered safety features and protection systems required to avoid undue risk to the health and safety of the public. This power source shall provide this capacity assuming a failure of a single active component.

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<sup>2</sup> In the Staff Requirements Memorandum for SECY-92-223, dated September 18, 1992 (ADAMS Accession No. ML003763736), the Commission decided not to apply the GDC to plants with construction permits issued prior to May 21, 1971. Pre-GDC plants were evaluated on a plant specific basis and are presumed to comply with the intent of the GDC because those licenses were granted using comparable evaluation criteria reflected in the FSAR.

Furthermore, some pre-GDC plants were approved for construction based on the proposed General Design Criteria that the AEC published for comment in the *Federal Register* (32 FR 10213) on July 11, 1967 (ADAMS Accession No. ML043310029), which stated:

The Atomic Energy Commission has under consideration an amendment to its regulation, 10 CFR Part 50, "Licensing of Production and Utilization Facilities," which would add an Appendix A, "General Design Criterion, for Nuclear Power Plant Construction Permits." The purpose of the proposed amendment would be to provide guidance to applicants in developing the principal design criteria to be included in applications for Commission construction permits. These General Design Criteria would not add any new requirements, but are intended to describe more clearly present Commission requirements to assist applicants in preparing applications.

The proposed amendment would complement other proposed amendments to Part 50 which were published for public comment in the *Federal Register* on August 16, 1966 (31 FR 10891). The proposed amendments to Part 50 reflect a recommendation made by a seven-member Regulatory Review Panel, appointed by the Commission to study:

(1) The programs and procedures for the licensing and regulation of reactors and (2) the decision-making process in the Commission's regulatory program. The Panel's report recommended the development, particularly at the construction permit stage of a licensing proceeding, of design criteria for nuclear power plants. Work on the development of such criteria had been in process at the time of the Panel's study.

As a result, preliminary proposed criteria for the design of nuclear power plants were discussed with the Commission's Advisory Committee on Reactor Safeguards and were informally distributed for public comment in Commission Press Release H-252 dated November 22, 1965. In developing the proposed criteria set forth in the proposed amendments to Part 50, the Commission has taken into consideration comments and suggestions from the Advisory Committee on Reactor Safeguards, from members of industry, and from the public... The Commission expects that the provisions of the proposed amendments relating to General Design Criteria for Nuclear Power Plant Construction Permits will be useful as interim guidance until such time as the Commission takes further action on them.....

The criteria are designated as General Design Criteria for Nuclear Power Plant Construction Permits to emphasize the key role they assume at this stage of the process. The criteria have been categorized as Category A or Category B. Experience has shown, that more definitive information is needed at the construction permit stage for the items listed in Category A than for those in Category B.

Applicable electric power system GDCs are:

Criterion 21-Single Failure Definition (Category B). Multiple failures resulting from a single event shall be treated as a single failure.

Criterion 24-Emergency Power for Protection Systems (Category B). In the event of loss of all offsite power, sufficient alternate sources of power shall be provided to permit the required functioning of the protection systems.

Criterion 39-Emergency Power for Engineered Safety Features (Category A). Alternate power systems shall be provided and designed with adequate independency, redundancy, capacity, and testability to permit the functioning required of the engineered safety features. As a minimum, the onsite power system and the offsite power system shall each, independently, provide this capacity assuming a failure of a single active component in each power system. [Note: Public comments<sup>3</sup> on Criterion 39 stated that the requirement that offsite power must satisfy the “single failure criterion” is impractical. The staff’s resolution stated, “The criterion has been rewritten to make it clear that the offsite power system need not meet the “single failure criterion.””

The AEC published the final rule that added 10 CFR Part 50, Appendix A, “General Design Criteria for Nuclear Power Plants,” in the *Federal Register* (36 FR 3255) on February 20, 1971, with the rule effective on May 21, 1971 (ADAMS Accession No. ML003674723).

The NRC staff reviewed a sample of NRC SERs that approved the electrical power system for pre-GDC plants and confirmed the NRC approvals were based on an evaluation of system functional performance against the principal design criteria in the FSAR which is consistent with NRC approvals against the specific GDC 17 requirements of this compliance exception.

**2) The prior NRC staff approval(s) of the licensee’s method of compliance with such “known and established standards;”**

For every nuclear power plant, all prior NRC staff approvals of the licensee’s method of compliance considered at least the plain language wording in 10 CFR Part 50, Appendix A, GDC 17 or the principal design criteria specified in the FSAR. The NRC approval process involves the NRC staff’s review of the plant specific set of facts in the licensee’s or applicant’s submittal and the NRC evaluation of these facts against known and established standards and conditions. The “Omitted Fact” described below is a design vulnerability that was not described or known in past licensee or applicant submittals or prior NRC approvals because this fact was revealed through operating experience following NRC approval. This “Omitted Fact” could result in a design that is not in compliance with the “known and established standards” at the time of original NRC approval.

**3) The specific omission or mistake of fact that undermines the prior NRC staff approval(s);**

An omitted fact (i.e. “new” information ) may be information which: (i) did not exist, (ii) was not recognized as relevant and significant by all relevant stakeholders; or (iii) could not have reasonably been known to all of the relevant stakeholders at the time of NRC staff approval. In this case, the Omitted Fact was an unknown design inadequacy (i.e., the offsite power protective relay scheme would not detect and isolate certain OPCs) which, had it been known at the time of original plant licensing, would have led to the NRC to conclude that the plant design was inadequate (i.e., did not meet (as applicable) GDC 17, the proposed GDC in the 1967 rule, the three AIF criteria, and the principle design criteria as set forth in pre-GDC plants. This omitted fact was discovered as a result of an operational event, and did not exist or could not have reasonably been known to all of the relevant stakeholders at the time of NRC staff approval.

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<sup>3</sup> Commission SECY Paper - SECY R-143, “Amendment to 10 CFR 50 - General Design Criteria for Nuclear Power Plants,” January 28, 1971 (ADAMS Accession No. ML072420278).

On January 30, 2012, an Unusual Event was declared for Byron Station, Unit 2, due to the mechanical failure of an under-hung porcelain insulator in the 345 kV feed common to both system auxiliary transformers. This created an open phase fault that caused a ground on one phase of the high voltage terminals of the system auxiliary transformers that the installed protective relay schemes for degraded grid voltage or loss of power were not designed to detect such that the two-out-of-two trip logic could be satisfied. As a result, the installed protective relaying did not perform its design function to detect the offsite power OPC and trip open the circuit breakers to disconnect offsite power from onsite power and cause the automatic starting of the emergency diesel generators and sequential loading of safety-related buses. The event impacted both Unit 2 redundant safety trains. The Unit 2 reactor tripped on reactor coolant pump bus undervoltage, and multiple motors tripped on overcurrent. Approximately 8 minutes after the reactor trip, the control room operators diagnosed the OPC and manually tripped breakers to separate the unit buses from the offsite power source.

The January 30, 2012, event revealed a previously unrecognized design vulnerability where the credited GDC 17 offsite power supply experienced an OPC that the existing protective relay schemes for degraded grid voltage or loss of power were not designed to detect such that the trip logic could be satisfied. Operating experience from other plants shows that with an OPC on the switchyard side of certain transformer designs, the two functioning phases will induce voltage to the open-circuited phase such that phase-to-phase voltage measurements<sup>4</sup> on the plant side of the transformers alone would not identify an open-circuited phase in a lightly loaded power line. The NRC and licensees at all nuclear plants have always known that open circuit faults are a credible failure mechanism and that an open circuit fault can occur on one, two, or all three phases of electrical power<sup>5</sup>. The “Omitted Fact” that was not known by the NRC or licensees was the design inadequacy of the existing protective relay schemes for degraded grid voltage or loss of power in that certain offsite power open phase fault conditions would not be detected to satisfy the trip logic. This unrecognized design vulnerability involving certain offsite power OPCs is an “Omitted Fact,” that was not addressed in established standards and was not considered by the NRC staff which undermines past NRC approvals in that the design of the electric power system was not in compliance with GDC 17, “Electric power systems,”<sup>6</sup> or the principal design criteria in the FSAR. If the offsite power OPC is not detected and isolated from the onsite power system, it may prevent the separation of the faulted offsite power system

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<sup>4</sup> While technical specification (TS) surveillance requirements require licensees to verify correct breaker alignment and indicated power availability for each required offsite circuit, plant operating experience describes instances of single or double OPCs that were undetected by the surveillances. NRC Administrative Letter 98-10, “Dispositioning of Technical Specifications That Are Insufficient to Assure Plant Safety,” states, “the discovery of an improper or inadequate TS value or required action is considered a degraded or nonconforming condition...Imposing administrative controls in response to an improper or inadequate TS is considered an acceptable short-term corrective action.”

<sup>5</sup> For example, the NRC Standard Review Plan, Section 8.2, “Offsite Power System,” for GDC 17 specifies that NRC staff evaluate electrical protective relaying to assure that loss of one offsite circuit will not result in loss of the redundant offsite source and that the physical arrangement is such that no single event such as a tower falling or a line breaking can simultaneously affect redundant offsite circuits.

<sup>6</sup> NRC Inspection Manual Chapter 0326, “Operability Determinations & Functionality Assessments for Conditions Adverse to Quality or Safety,” states that a structure, system, or component is considered “not fully qualified,” i.e., degraded or nonconforming, when it does not conform to all aspects of its current licensing basis [CLB]... .” This compliance exception documented evaluation supports changing the current licensing basis for operating nuclear reactors to require that the electric power system meet GDC 17 or the principal design criteria in the FSAR assuming all potential open phase conditions in offsite power.

and impede the transfer of loads to an alternate offsite power source or emergency onsite power source.

The known and established standards used for NRC approvals not only did not address the OPC "Omitted Fact," these standards never state or imply that the standards provide a complete list of items to base compliance and as such, never allow excluding from consideration a fact not covered by the standard that is contrary to the regulation itself. In this case, operating experience revealed an unrecognized OPC design vulnerability not addressed by known and established standards at the time of licensing that the electrical power system did not meet a performance function stated in regulation GDC 17, as described further below. Although NRC Standard Review Plan, Section 8.2, "Offsite Power System," lists several regulatory guides, such as Regulatory Guide 1.32, "Criteria for Power Systems for Nuclear Power Plants," Rev. 1, 1976 (ADAMS Accession No. ML13226A208); Regulatory Guide 1.75, "Physical Independence of Electrical Systems," Rev. 1, 1975 (ADAMS Accession No. ML13350A340), that describe methods acceptable to the NRC staff for meeting select aspects of GDC 17, regulatory guides do not, and are not intended to, provide complete lists of items to establish compliance.

For example, the following excerpt from Regulatory Guide 1.32 describes methods acceptable to the NRC staff for meeting select aspects of GDC 17. This regulatory guide does not provide a complete list of items to base compliance and does not state or imply it permissible to exclude from consideration a fact not covered by the regulatory guide that is contrary to the electric power system performance function stated in regulation GDC 17 itself. Specifically, Regulatory Guide 1.32, Section C, "Regulatory Position," states:

1. For the portion of safety-related electric power system within its scope, the criteria, requirements, and recommendations in IEEE Std 308-1974 are generally acceptable to the NRC staff and provide an adequate basis for complying with the Commission's General Design Criteria 17 and 18 of Appendix A to 10 CFR Part 50 with respect to the design, operation, and testing of electric power systems, subject to the following:

- a. Availability of Offsite Power.* Consistent with the requirements of Criterion 17, the phrase "within an acceptable time" in Section 5.2.3(4), first paragraph, of IEEE Std 308-1974 should be construed to mean "within a few seconds." A preferred design would include two immediate access circuits from the transmission network. Detailed guidance for operating procedures and restrictions acceptable to the staff, applicable where two immediate access circuits are available, is contained in Regulatory Guide 1.93, "Availability of Electric Power Sources." An acceptable design would substitute a delayed access circuit for one of the immediate access circuits provided the availability of the delayed access circuit conforms to Criterion 17.

- b. Battery Charger Supply.* The capacity of the battery charger supply should be based on the largest combined demands...

- c. Battery Performance Discharge Tests.* The test interval for the battery performance discharge test should be as specified in IEEE Std 450-1975...

- d. Independence of Redundant Standby Sources.* Electrical independence between redundant standby (onsite) power sources should be in accordance with Regulatory Guide 1.6. Physical independence should be in accordance with Regulatory Guide 1.75.

*e. Connection of Non-Class IE Equipment to Class IE Systems.* The guidance presented in Regulatory Guide 1.75 should be followed.

*f. Selection of Diesel Generator Set Capacity for Standby Power Supplies.* The guidance presented in Regulatory Guide 1.9 should be followed.

2. The following optional practices are considered to be unacceptable as given below:

*a. Shared Electric Systems for Multi-Unit Nuclear Power Plants.* The provisions of Section 8.2 of IEEE Std 308-1974, which permit sharing of standby power supplies among units of a multi-unit station, are unacceptable except as specified in Regulatory Guide 1.81. ...

*b. Availability of Electric Power Sources.* Table 3, "Suggested Operating Alternatives with Degraded Class IE Power System Conditions," of IEEE Std 308-1974 is considered unacceptable and should be supplanted by the recommendations of Regulatory Guide 1.93.

**4) An evaluation explaining that, but-for the identified omission or mistake of fact, the NRC staff would not have issued the prior approval; and**

Given the identified "Omitted Fact" described above, the NRC staff would not have issued the prior approvals because the design of the electric power system would not be in compliance with GDC 17. Specifically,

General Design Criterion 17, "Electric Power Systems," states in part, "An onsite electric power system and an offsite electric power system shall be provided to permit functioning of structures, systems, and components important to safety. The safety function for each system (assuming the other system is not functioning) shall be to provide sufficient capacity and capability to assure that (1) specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded as a result of anticipated operational occurrences, and (2) the core is cooled and containment integrity and other vital functions are maintained in the event of postulated accidents...."

Contrary to GDC 17, the safety function of the onsite power system (assuming the offsite system is not functioning as a result of the previously unrecognized and omitted design vulnerability of an open phase condition) fails to performing its safety function to provide sufficient capacity and capability to assure that (1) specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded as a result of anticipated operational occurrences, and (2) the core is cooled and containment integrity and other vital functions are maintained in the event of postulated accidents...." in that the onsite power system fails to transfer automatically to the alternate onsite standby power system within the time assumed in the accident analysis.

General Design Criterion 17, "Electric Power Systems," states in part, "Provisions shall be included to minimize the probability of losing electric power from any of the remaining supplies as a result of, or coincident with, the loss of power generated by the nuclear power unit, the loss of power from the transmission network, or the loss of power from the onsite electric power supplies."

Contrary to GDC 17, inadequate provisions have been included to detect and isolate certain offsite power open phase fault conditions to minimize the probability of losing electric power from the onsite power supplies as a result of, or coincident with, the loss of power under these open phase conditions from the transmission network.

Given that the GDC 17 requirements was one of the fundamental parts of the framework for reviewing and finding a design to be adequate, it compels the conclusion that if the vulnerability from offsite power open phase fault was understood at the time of licensing, the design would not have been found to meet this criterion.

**5) A description of how the NRC has interpreted the “known and established standards” at issue (with respect to the specific licensee in the case of a facility-specific backfit, or generically in the case of a generic backfit).**

As described above, the NRC has used a consistent interpretation of GDC 17 that starts with the plain language wording of the GDC. Regulatory guidance documents have been consistent allowing a finding that the standard as applied throughout the period of licensing of these plants has not changed would not have been met by the approved designs if there had been an understanding of the open phase impacts on the plant. The compliance issue related to this generic backfit is based on “omitted facts” at the time of design approval in that the well-established criteria at that time would have resulted in different action by the staff if the information had been known.