INTERAGENCY AGREEMENT	1. IAA NO. NRC-HQ-60-14-D-0023/M0005	PAGE 1 OF 2

2. ORDER NO.	3. REQUISITION NO. RES-16-0104	4 SOLICITATION NO.

5. EFFECTIVE DATE	6. AWARD DATE	7. PERIOD OF PERFORMANCE
01/21/2016	01/21/2016	09/04/2014 TO 05/31/2016

8 SERVICING AGENCY
BROOKHAVEN NATIONAL LABORATORY
ALC:
DUNS: 027579460 +4:
BROOKHAVEN SITE OFFICE
PO BOX 5000 BLDG 464
UPTON NY 11973-5000

POC KIM NEKULAK
TELEPHONE NO. 631-344-7439

9. DELIVER TO
MAURICIO GUTIERREZ
US NUCLEAR REGULATORY COMMISSION
TWO WHITE FLINT BUILDING
11545 ROCKVILLE PIKE
MAIL STOP T-10A36
ROCKVILLE MD 20852

10. REQUESTING AGENCY
ACQUISITION MANAGEMENT DIVISION
ALC: 31000001
DUNS: 040535809 +4:
US NUCLEAR REGULATORY COMMISSION
TWO WHITE FLINT NORTH
11545 ROCKVILLE PIKE
MAIL STOP T-5E3
ROCKVILLE MD 20852-2738
POC Carolyn A. Cooper
TELEPHONE NO. (301) 415-6734

11. INVOICE OFFICE
US NUCLEAR REGULATORY COMMISSION
ONE WHITE FLINT NORTH
11555 ROCKVILLE PIKE
MAILSTOP O3-E17A
ROCKVILLE MD 20852-2738

12 ISSUING OFFICE
US NRC - HQ
ACQUISITION MANAGEMENT DIVISION
MAIL STOP TWFN-5E03
WASHINGTON DC 20555-0001

13. LEGISLATIVE AUTHORITY
Energy Reorganization Act of 1974

14. PROJECT ID

15. PROJECT TITLE
DC POWER SYSTEM FAULT CONTRIBUTIONS FROM BATTERIES

16 ACCOUNTING DATA
2016-X0200-FEEBASED-60-60D001-11-6-213-1007-253D

17. ITEM NO.	18. SUPPLIES/SERVICES	19. QUANTITY	20. UNIT	21. UNIT PRICE	22. AMOUNT
	NRC-HQ-60-14-D-0023 Master IAA: N/A The purpose of this modification is to incorporate a within scope change to the Statement of Work as reflected in Attachment 1, thereby increasing the authorized ceiling amount of the agreement by $72,028.00 from $685,995.00 to $758,023.00; increasing the amount obligated in the agreement by $72,028.00, from $685,995.00 to $758,023.00; and extending the period of performance to May 31, 2016. Accordingly, the agreement is hereby modified: Continued ...				

23 PAYMENT PROVISIONS	24. TOTAL AMOUNT
	$72,028.00

25a SIGNATURE OF GOVERNMENT REPRESENTATIVE (SERVICING)	26a. SIGNATURE OF GOVERNMENT REPRESENTATIVE (REQUESTING)
Kim M. Nekulak Contracting Officer	Carolyn A. Cooper
25b NAME AND TITLE	**25c. DATE**	**26b. CONTRACTING OFFICER**	**26c. DATE**
Kim M. Nekulak, Contracting Officer	FEB 18 2016	CAROLYN A. COOPER	1/21/2016

TEMPLATE - ARM001

SUNSI REVIEW COMPLETE

MAR 18 2016

ARM002

TOTAL AMOUNT OBLIGATED THIS ACTION: $72,028
TOTAL AUTHORIZED CEILING AMOUNT: $758,023 (changed)
TOTAL AMOUNT OBLIGATED: $758,023 (changed)
PERIOD OF PERFORMANCE: September 4, 2014 through May 31, 2016 (changed)

The following document is hereby incorporated into the Agreement: Attachment 1, Revised Statement of Work

ALC: 31000001 DUNS: 040535809
TAS: 31X0200.320

All other terms and conditions of the subject agreement remain unchanged.

Statement of Work

NRC Agreement Number	NRC Agreement Modification Number	NRC Task Order Number (If Applicable)	NRC Task Order Modification Number (If Applicable)
NRC-HQ-60-14-D-0023	Modification 0005		

Project Title
DC Power System Fault Contributions from Batteries and Battery Chargers Used in Nuclear Power Plants

Job Code Number	B&R Number	DOE Laboratory
		BNL

NRC Requisitioning Office
RES/DE

NRC Form 187, Contract Security and Classification Requirements	
☐ Applicable x Not Applicable	☐ Involves Proprietary Information ☐ Involves Sensitive Unclassified
☒ Non Fee-Recoverable	☐ Fee-Recoverable (If checked, complete all applicable sections below)
Docket Number (If Fee-Recoverable/Applicable)	**Inspection Report Number (If Fee Recoverable/Applicable)**
Technical Assignment Control Number (If Fee-Recoverable/Applicable)	**Technical Assignment Control Number Description (If Fee-Recoverable/Applicable)**

This Statement of Work is being modified to reflect concerns raised by RIII and RES staff following test results obtained from the original Task 3 testing results. As a result, the period of performance is being extended from completion in February 2016 to May 2016.

1.0 BACKGROUND

On September 25, 2011, at Palisades Nuclear Plant on the left train of DC power, both the battery charger and the battery tripped on overcurrent, when a fault occurred on the downstream DC panel (Information Notice 2013-17). As a result of the event, a Special Inspection Team (SIT) was assembled. The complete details of this event are provided in the SIT Report (ADAMS Accession No. ML113330802). More specifically, on page 47 of the SIT report, the following is stated:

> "According to Ametek, the manufacturer of the battery charger, the current-limiting feature of the battery chargers were not immediate (38 millisecond time delay) and were

not designed to protect against large, instantaneous DC faults. Because the fault current was very high, the battery charger tripped before the current limiter was able to respond and compensate. This phenomenon was also discussed in IEEE-946-2004, "IEEE Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Station."

IEEE Std 946-2004 Subclause 7.9.2 states: "When the battery charger is connected in parallel with the battery, the battery capacitance will prevent the battery charger contribution from rising instantaneously. Therefore the maximum current that a charger will deliver on short circuit will not typically exceed 150% of the charger full load ampere rating. Instantaneous battery charger current rise should only become a concern during periods when the battery is disconnected." The statements in IEEE 946-2004 related to the nature of these contributions appear contrary to what actually transpired at the Palisades Plant in September 2011. Therefore, there's a need to determine whether the individual short circuit current contributions of a battery and a battery charger are independent of each other in a typical nuclear power plant dc system configuration. This is necessary so that engineering measures such as protective device coordination can limit the impacts of such an event. The NRC staff currently considers that the statement in IEEE Std 946-2004, Subclause 7.9.2, "Instantaneous battery charger current rise should only become a concern during periods when the battery is disconnected," is incorrect and is being applied erroneously. The staff believes that instantaneous battery charger current rise should be dependent only on the battery charger design and not whether the battery is connected or disconnected. Therefore, the battery charger short circuit protection should take into consideration the initial short circuit current rise during the first approximately 100 milliseconds of the fault occurrence. Based on IEEE 946-2004 it appears that at most nuclear plants, the battery charger protection and its coordination with downstream devices is limited to 150% of the charger full load ampere rating.

2.0 OBJECTIVE

The objective of this project is to compile information needed for NRC to evaluate whether the individual short circuit current contributions to the downstream fault by the battery charger and the battery are independent and determine how they are related to each other in the design of DC auxiliary power systems for generating systems. Another objective is to develop a technical report that confirms whether the individual short circuit current contributions to the downstream fault by the battery charger and the battery are independent of each other when the battery and the battery charger are connected together, during the first 100 milliseconds of a fault occurrence. This information is necessary so that engineering measures such as protective device coordination can limit the impacts of a fault event.

This report may be used by the NRC to provide the technical basis for future regulatory actions which could include conducting further plant assessments, writing an Information Notice,

developing a regulatory guide endorsing IEEE 946 with comments, or possibly influencing the updating of the IEEE Standard to reflect the current state of art.

3.0 SCOPE OF WORK (MODIFIED)

Brookhaven National Laboratory (BNL) shall provide all the personnel, equipment, facilities and other resources necessary to accomplish the tasks and provide the deliverables described in this modified statement of work (SOW). BNL shall test and determine the short circuit characteristics performance of the three types of chargers that are typically used in the nuclear plants (which are the silicon controlled rectifier (SCR) (SCR type being the most dominant one), and controlled – ferro-resonant (CFR). The testing shall be inclusive as possible of the charger types in safety related applications.

The results of above tests should confirm individual short circuit current contributions to the downstream fault by the battery and battery charger and provide further evidence of the capabilities and contributions of a combined charger and battery test.

Additional testing will be performed to determine the battery voltage response to a short-circuit transient during specifics fault clearing times which are representative of the protective devices used in a nuclear power plants. These protective devices have a certain amount of uncertainty in the instantaneous regions by design, as well as tolerance errors for the tripping features and these data points will bound the worst case for a fault clearing time. Assistance will be provided to NRC staff for dissemination of results and conclusions to key stakeholders.

4.0 SPECIFIC TASKS

BNL shall perform the following tasks:

Task 1 – REVIEW KNOWLEDGE-BASE FOR BATTERY AND CHARGER VENDORS

1. BNL shall conduct a detailed technical review of dc power distribution schemes, technical papers, previous testing by battery and battery charger vendors for fault current information, types of chargers being used, batteries and charger vendor data to determine the knowledge-base that exists for determining the fault current contributions from batteries and battery chargers.

2. BNL shall confer with the IEEE Standard Working Group to gather further input.

3. BNL shall prepare back-up test alternatives for the unknowns/risks that can be present during the testing phase due to the high fault currents.

Task 2 – DEVELOP TEST PLAN

1. BNL shall develop a test plan via the knowledge-base that exists for determining the combined fault current contributions from the batteries and battery chargers. The test plan shall define the engineering measures, such as protective device coordination, that are applicable and can potentially limit the impacts of a similar fault event.

   The test plan shall delineate the number of tests to be conducted, the types of battery chargers to be tested (e.g., SCR, controlled ferro-resonant transformer and IGBT) and the anticipated results.

2. BNL shall submit the draft test plan to the NRC COR for review and comment and revise the draft test plan incorporating the NRC's review comments. BNL shall submit the final test plan to the NRC COR for review and approval. NRC will provide approval to BNL no later than two weeks after receipt of final test plan.

Task 3 – CONDUCT TESTING OF BATTERIES AND BATTERY CHARGES (MODIFIED)

1. BNL shall conduct testing of representative battery chargers and batteries used in nuclear power plants. Based on the results of Task 1, select the specific types and models of battery chargers to be tested. **NOTE: Three additional (3) tests on each battery charger used should be sufficient to gain a better understanding of the short circuit contribution of chargers in a nuclear DC power system and bound the worst case for the fault clearing time for protective devices at a plant distribution system in the NPP.**

2. The following tests shall be performed:

   (a) With SCR type battery charger: Performance short-circuit tests (a) with the battery disconnected from the battery charger, record the current contribution from the battery charger, during the first 100 milliseconds, when the short circuit is created at the terminals of battery charger; (b) with the battery charger disconnected from the battery, record the current contribution from the battery, during the first 100 milliseconds, when the short circuit is created at the terminals of battery; (c) with battery connected to the battery charger, record the current contribution from each of the battery charger, and the battery individually, during the first 100 milliseconds, when the short circuit is created at the connecting bus bar link connecting the battery charger and the battery

   (b) With ferro-resonant type battery charger: Perform the same tasks as in (a).

(c) Testing will be performed on each of the three battery strings in combination with the battery chargers (representative of a typical DC system configuration in a nuclear power plant) to determine the voltage response to a short circuit transient during representative clearing times for protective devices used in nuclear power plants. Three clearing times: 0.1 seconds, 0.3 seconds, and 0.5 seconds will be tested for each battery string-charger combination.

3. BNL shall consult with an experienced subcontractor for technical specialized experience with fault testing of batteries in order to provide BNL with detailed information regarding the experimental set-up used in the past. The subcontractor shall also advise BNL on how to adapt the past experimental work to BNL's battery and battery charger arrangements. The subcontractor shall assist BNL with the selection of monitoring equipment to accurately and safely record the required data.

4. BNL shall purchase the class 1E battery chargers and calibrated test equipment needed for the test (existing batteries will be used).

5. BNL shall set up the test for review and approval by the NRC. Upon receipt of NRC approval, BNK shall conduct the tests in accordance with the approved test plan. BNL shall implement nine different combinations of tests, for example, 3 tests with battery only, 3 tests with battery charger only (different charger types), and 3 tests with combined battery and battery charger.

Task 4 – DEVELOP TEST REPORT

BNL shall review and analyze the results of the testing conducted and document the results in a draft test report. BNL shall submit the draft test report to the NRC COR for review and comment. Upon receipt of the NRC review comments, BNL shall revise the report incorporating the NRC's comments and submit the final test report NRC review and approval.

Task 5 – SUPPORT NRC STAFF IN DISSEMINATION OF RESULTS (NEW TASK)

BNL will assist NRC in dissemination of results for purposes of awareness and for consideration of appropriate standards revisions. Details of travel that may be required for dissemination of results is detailed in Section 7.0 of this Statement of Work.

5.0 DELIVERABLES AND/OR MILESTONES SCHEDULE (MODIFIED)

The following table provides the estimated due dates for submission of the deliverables. In all cases, the date indicated for submission of the deliverables includes time for discussion with the NRC COR to ensure that the "final" product will be acceptable. Delay in the completion of any deliverable will not result in automatic delay in the due date of subsequent deliverables. The schedule may be modified at the discretion of the NRC COR.

Task	Deliverable	Deadline	Additional Comments
1.1	Conduct detailed technical review	11/1/2014	Gather all information from available sources
2.1	Develop draft test plan	2/28/2015	NRC comments will be provided in 8 weeks after receipt of draft plan
2.2	Submit Final Test Plan	5/15/2015	NRC approval will be provided within 2 weeks after receipt of final plan
3	Conduct Testing	**1/29/2016**	In accordance with approved Final Test Plan
4	Develop Draft Test Report	**2/29/2016**	NRC comments will be provided within two weeks after receipt of draft test report
4	Submit Final Test Report	**5/20/2016**	NRC approval will be provided within 2 weeks after receipt of final report.

6.0 TECHNICAL AND OTHER SPECIAL QUALIFICATIONS REQUIRED

Specialized experience must include expertise in such areas as batteries, battery testing, monitoring, and battery charger applications. In addition, experience is required in the following:

a. Shunts
b. Fuses
c. Breakers
d. Automatic switching
e. Back-up test shut down capabilities.

2. Understanding of high fault currents and how the batteries and chargers will respond.
3. Extensive expertise in testing batteries and evaluating their capabilities as evidenced by publication of research papers and technical reports directed toward expert and general audiences.
4. Familiarity with regulations and guidance of the United States Nuclear Regulatory Commission applicable laws and requirements.

7.0 MEETINGS AND TRAVEL (MODIFIED)

The information below is provided in order to permit a more precise estimate of the costs involved in performance of the work. The need for and details of these trips will be worked out cooperatively between BNL and the NRC COR. All travel must be approved by the NRC PO.

1. Attend the IEEE Stationary Battery Working Group Winter Meeting (held between 1/10/2016 - 1/15/2016 to present and discuss results of the experiments conducted as described in Task 3 for consideration to revise the relevant IEEE Standard 946 "IEEE Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Systems". Feedback on the results from the working group will also be obtained.

2. Attend and present a paper on the results and conclusion of the experiments conducted as described in Task 3 at the 2016 Battcon Conference (held between May 10-12, 2016). Feedback on the results and conclusions will be obtained.

Deviations from this travel submitted will be coordinated with the NRC Contracting Officer's Representative is a need is identified.

8.0 REPORTING REQUIREMENTS

The DOE Laboratory is responsible for structuring the deliverable to follow agency standards. The current agency standard is Microsoft Office Suite 2010. The current agency Portable Document Format (PDF) standard is Adobe Acrobat 9 Professional. Deliverables must be submitted free of spelling and grammatical errors and conform to requirements stated in this section.

In addition to any reports required as deliverables under this task order, the laboratory will be responsible for submitting a monthly status report to the cognizant Contracting Officer Representative (COR) with copies to the NRC Contracting Officer (CO) and/or Contract Specialist.

9.0 CONTRACTING OFFICER'S REPRESENTATIVE

The COR monitors all technical aspects of the agreement/task order and assists in its administration. The COR is authorized to perform the following functions: assure that the DOE Laboratory performs the technical requirements of the agreement/task order; perform inspections necessary in connection with agreement/task order performance; maintain written and oral communications with the DOE Laboratory concerning technical aspects of the agreement/task order; issue written interpretations of technical requirements, including Government drawings, designs, specifications; monitor the DOE Laboratory's performance and notify the DOE Laboratory of any deficiencies; coordinate availability of NRC-furnished material and/or GFP; and provide site entry of DOE Laboratory personnel.

Contracting Officer's Representative

Name: Mauricio Gutierrez
Agency: U.S. Nuclear Regulatory Commission
Mail Stop: T-10A36
Washington, DC 20555-0001
E-Mail: Mauricio.gutierrez@nrc.gov
Phone: (301) 415-1925

10.0 MATERIALS REQUIRED

Specific types and models of battery chargers will be selected for testing. Other materials required are: calibrated shunt, fuses, breakers, copper bus bars, high speed data recording device(s), and automatic switching. BNL will be responsible for purchasing these items under this agreement.

11.0 NRC-FURNISHED PROPERTY/MATERIALS

N/A

12.0 RESEARCH QUALITY

The quality of NRC research programs are assessed each year by the Advisory Committee on Reactor Safeguards. Within the context of their reviews of RES programs, the definition of quality research is based upon several major characteristics:

Results meet the objectives (75% of overall score)

- Justification of major assumptions (12%)
- Soundness of technical approach and results (52%)
- Uncertainties and sensitivities addressed (11%)

Documentation of research results and methods is adequate (25% of overall score)

- Clarity of presentation (16%)
- Identification of major assumptions (9%)

It is the responsibility of the DOE Laboratory to ensure that these quality criteria are adequately addressed throughout the course of the research that is performed. The NRC COR will review all research products with these criteria in mind.

13.0 STANDARDS FOR CONTRACTORS WHO PREPARE NUREG-SERIES MANUSCRIPTS

The U.S. Nuclear Regulatory Commission (NRC) began to capture most of its official records electronically on January 1, 2000. The NRC will capture each final NUREG-series publication in its native application. Therefore, please submit your final manuscript that has been approved by your NRC Project Manager in both electronic and camera-ready copy.

The final manuscript shall be of archival quality and comply with the requirements of NRC Management Directive 3.7 "NUREG-Series Publications." The document shall be technically edited consistent with NUREG–1379, Rev. 2 (May 2009) "NRC Editorial Style Guide." The goals of the "NRC Editorial Style Guide" are readability and consistency for all agency documents.

All format guidance, as specified in NUREG-0650, "Preparing NUREG-Series Publications," Rev. 2 (January 1999), will remain the same with one exception. You will no longer be required to include the NUREG-series designator on the bottom of each page of the manuscript. The NRC will assign this designator when we send the camera-ready copy to the printer and will place the designator on the cover, title page, and spine. The designator for each report will no longer be assigned when the decision to prepare a publication is made. The NRC's Publishing Services Branch will inform the NRC Project Manager for the publication of the assigned designator when the final manuscript is sent to the printer.

For the electronic manuscript, the Contractor shall prepare the text in Microsoft Word, and use any of the following file types for charts, spreadsheets, and the like.

File Types to be Used for NUREG-Series Publications	
File Type	File Extension
Microsoft®Word®	.doc
Microsoft® PowerPoint®	.ppt
Microsoft®Excel	.xls
Microsoft®Access	.mdb
Portable Document Format	.pdf

This list is subject to change if new software packages come into common use at NRC or by our licensees or other stakeholders that participate in the electronic submission process. If a portion of your manuscript is from another source and you cannot obtain an acceptable electronic file type for this portion (e.g., an appendix from an old publication), the NRC can, if

necessary, create a tagged image file format (file extension.tif) for that portion of your report. Note that you should continue to submit original photographs, which will be scanned, since digitized photographs do not print well.

If you choose to publish a compact disk (CD) of your publication, place on the CD copies of the manuscript in both (1) a portable document format (PDF); (2) a Microsoft Word file format, and (3) an Adobe Acrobat Reader, or, alternatively, print instructions for obtaining a free copy of Adobe Acrobat Reader on the back cover insert of the jewel box.

14.0 OTHER CONSIDERATIONS: N/A

Access to Non-NRC Facilities/Equipment: N/A

Applicable Publications: N/A

Controls over document handling and non-disclosure of materials: **N/A**