



Memorandum from the Office of the Inspector General

August 2, 2021

Aaron P. Melda

**REQUEST FOR FINAL ACTION – EVALUATION 2020-15768 – TRANSMISSION AND
POWER SUPPLY ARC FLASH PROTECTION**

Attached is the subject final report for your review and final action. Your written comments, which addressed your management decision and actions planned or taken, have been included in the report. Please notify us when final action is complete. In accordance with the Inspector General Act of 1978, as amended, the Office of the Inspector General is required to report to Congress semiannually regarding evaluations that remain unresolved after 6 months from the date of report issuance.

If you have any questions or wish to discuss our findings, please contact Kristin S. Leach, Senior Auditor, at (423) 785-4818 or E. David Willis, Director, Evaluations, at (865) 633-7376. We appreciate the courtesy and cooperation received from your staff during the evaluation.

David P. Wheeler
Assistant Inspector General
(Audits and Evaluations)

KSL:FAJ

Attachment

cc (Attachment):

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OIG File No. 2020-15768



Office of the Inspector General

Evaluation Report

To the Senior Vice
President, Transmission and
Power Supply

TRANSMISSION AND POWER SUPPLY ARC FLASH PROTECTION

Evaluation Auditor
Kristin S. Leach

Evaluation 2020-15768
August 2, 2021

ABBREVIATIONS

BU	Business Unit
Cal/cm ²	Calories per Centimeter Squared
CFR	Code of Federal Regulations
ECM	Enterprise Content Management
kV	Kilo-volt
OSHA	Occupational Safety and Health Administration
PPE	Personal Protective Equipment
SPP	Standard Programs and Processes
TPS	Transmission and Power Supply
TSP	TVA Safety Procedure
TVA	Tennessee Valley Authority

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MEMORANDUM DATED JULY 28, 2021, FROM AARON MELDA TO
DAVID P. WHEELER



Evaluation 2020-15768 – Transmission and Power Supply Arc Flash Protection

EXECUTIVE SUMMARY

Why the OIG Did This Evaluation

According to the Occupational Safety and Health Administration, workers in the electric power industry are potentially exposed to a variety of serious hazards that can cause injury and death such as electric shock, thermal burn, and arc flash. An arc flash event can expel large amounts of deadly energy. Tennessee Valley Authority's (TVA) medical records system indicated there were seven arc flash injuries between 2015 and 2020. Of the seven, one of the injuries occurred in 2017 at a Transmission and Power Supply (TPS) site.

Due to the risk of personnel injury from arc flash hazards, we initiated this evaluation to determine if TPS was performing arc flash procedures as required.ⁱ

What the OIG Found

We determined some requirements of TVA procedures were not performed. Specifically, (1) some arc flash hazard analyses were not performed, (2) arc flash hazard analyses were not periodically reviewed, (3) some arc flash hazard analyses were incomplete or inaccurate, and (4) some hazards were not accurately communicated on warning labels as required. In addition, we found arc flash hazard calculations were not formatted, approved, or maintained as required. We also determined personal protective equipment was maintained and most training was completed as required by the arc flash procedure; however, we identified a few individuals who had not completed the assigned curriculum. Lastly, we identified an opportunity for improvement related to developing a TPS-specific arc flash procedure.

Based on issues identified during the course of our evaluation, TPS performed an assessment of its arc flash program and developed an action plan to address identified gaps.

What the OIG Recommends

We recommend TVA management (1) take actions to address arc flash hazard analyses and calculation deficiencies, (2) verify appropriate personnel receive arc flash training, and (3) continue with planned improvements, including developing a TPS-specific procedure related to arc flash protection.

ⁱ TVA Safety Procedure 18.1022, *Arc Flash Protection*, establishes requirements for minimizing risk when working around equipment that poses an arc flash hazard.



Evaluation 2020-15768 – Transmission and Power Supply Arc Flash Protection

EXECUTIVE SUMMARY

TVA Management's Comments

In response to our draft report, TVA management agreed with our recommendations and provided planned actions. See the Appendix for TVA's complete response.

Auditor's Response

We concur with TVA management's planned actions for the recommendations.

BACKGROUND

According to the Occupational Safety and Health Administration (OSHA), workers in the electric power industry are potentially exposed to a variety of serious hazards that can cause injury and death such as electric shock, thermal burn, and arc flash. An arc flash event can expel large amounts of deadly energy. Arc flash temperatures can reach as high as 35,000 degrees Fahrenheit, which can set fire to clothing and severely burn human skin in fractions of a second at a significant distance from the event. The large amounts of energy expelled from an arc flash can result in severe burns, temporary or permanent hearing loss, blindness, nerve damage, cardiac arrest, and potential death. When workers can be exposed to electrical arcs, OSHA indicates the first effort should be to eliminate the exposure through engineering design. If elimination is not possible, exposures should be limited through other means, including work practices.

Tennessee Valley Authority (TVA) Safety Procedure (TSP) 18.1022, *Arc Flash Protection*, establishes requirements for minimizing risk when working around equipment that poses an arc flash hazard. Business units (BU) are required to identify and analyze electrical circuits and equipment that can develop arc flash exposure potential for voltages greater than, or equal to, 480 volts and up to 500 kilo-volts (kV). For analyzed equipment, arc flash hazard analyses¹ provide calculated values for the worst-case potential exposure for the following:

- **Incident Energy** – The amount of energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. Incident energy is measured in calories per centimeter squared (cal/cm²).
- **Flash Protection Boundary** – An approach limit established at the distance from an exposed live part within which a person without personal protective equipment (PPE) could receive a second degree burn if an electrical arc flash were to occur (second degree burns can occur at 1.2 cal/cm²).

When analyses are complete, TVA-TSP-18.1022 requires posting of signs or labels on equipment that can develop an incident energy greater than, or equal to, 1.2 cal/cm². Labels are required to be updated if calculations change. See Illustration 1 for an example of an arc flash label at a substation. Such labels must include the incident energy potential, flash

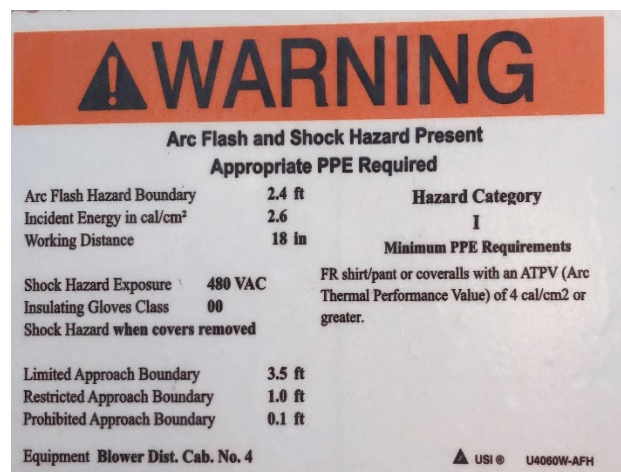


Illustration 1: Arc Flash Warning Label at Hiwassee 500kV substation.

¹ According to Transmission and Power Supply (TPS) personnel, Outdoor Conduit and Lightning Plan and Details drawings are the official record of arc flash hazard analyses.

protection boundary needed for work at that location, and level of PPE required. The PPE level required to conduct work at a location is determined by the calculated incident energy. TVA-TSP-18.1022 requires personnel who enter a defined and marked arc flash protection boundary to have training. In addition, TVA Standard Programs and Processes (SPP) 09.001, *Engineering Calculations*, requires all new and newly revised calculation packages become permanent TVA records by inputting them into TVA's Enterprise Content Management (ECM) system to ensure safekeeping of records and to have them readily retrievable.

TVA's medical records system indicated there were seven arc flash injuries between 2015 and 2020. Of the seven, one of the injuries occurred in 2017 at a TPS site. Due to the risk of personnel injury from arc flash hazards, we initiated this evaluation of TPS arc flash protection.

OBJECTIVE, SCOPE, AND METHODOLOGY

The objective of our evaluation was to determine if TPS was performing arc flash procedures as required. The scope of our evaluation included hazard analyses for 500kV sites,² PPE, and arc flash training. To achieve our objective, we:

- Interviewed the following pertinent personnel to gain an understanding of the arc flash protection process, requirements, and potential areas for improvement:
 - Corporate safety personnel
 - Transmission Service Center managers
 - Substation and Telecom Engineering personnel
 - Transmission Planning and Asset Management personnel
 - TPS Safety operations manager
- Reviewed the following documents to gain an understanding of the arc flash protection process and identify potential areas for improvement:
 - TVA-TSP-18.1022, *Arc Flash Protection*
 - TVA-SPP-09.001, *Engineering Calculations*
 - Title 29, Code of Federal Regulations (CFR), Section 1910.269 (29 CFR §1910.269) – *Electrical Power Generation, Transmission, and Distribution*
 - 29 CFR 1910 Subpart S – *Electrical*
 - *National Fire Protection Association Standard for Electrical Safety in the Workplace (70E)*
- Reviewed arc flash hazard analyses for 19 out of 53 500kV sites to determine if the hazard analyses met the requirements of the arc flash procedure.³
- Analyzed data to determine if individuals had received required training. We identified arc flash training courses required. We obtained records as of

² According to TPS personnel, 500kV sites would have high-hazard energy requiring hazard analyses.

³ TPS only provided hazard analyses for 19 of the 53 500kV sites.

November 30, 2020, for (1) active personnel assigned to the arc flash curriculum from TVA's human resource management system (2) training completion records from TVA's learning management system.

- Conducted site visits at 6 judgmentally selected 500kV sites to observe electrical equipment associated with hazard analysis, warning labels, and any PPE available onsite. The 6 sites (Franklin, Hiwassee, Plateau, Madison, Rutherford and Widows Creek) were selected based on (1) location to Chattanooga, Tennessee, in an effort to limit travel due to the COVID-19 pandemic and (2) types of arc flash hazard documentation provided for each location.⁴ At each site, we reviewed warning labels to determine if they (1) reflected arc flash hazard analyses and (2) had the minimum requirements of TVA-TSP-18.1022, including flash hazard boundary, arc flash energy (calorie rating), shock hazard, minimum approach, PPE category rating, and equipment location.
- Reviewed condition reports⁵ from November 12, 2015, through November 12, 2020, to determine if there were any concerns related to arc flash in TPS.

This evaluation was performed in accordance with the Council of the Inspectors General on Integrity and Efficiency's *Quality Standards for Inspection and Evaluation*.

FINDINGS

We determined some requirements of TVA-TSP-18.1022, *Arc Flash Protection*, were not performed. In addition, we found arc flash hazard calculations were not formatted, approved, or maintained in ECM as required by TVA-SPP-09.001, *Engineering Calculations*. We also determined PPE was maintained, and most training was completed as required by the arc flash procedure; however, we identified a few individuals who had not completed the assigned curriculum. Lastly, we identified an opportunity for improvement related to developing a TPS-specific arc flash procedure.

SOME REQUIREMENTS OF TVA'S ARC FLASH PROCEDURE WERE NOT PERFORMED

We determined some requirements of TVA-TSP-18.1022, *Arc Flash Protection*, were not performed. Specifically, (1) some arc flash hazard analyses were not performed, (2) hazard analyses were not periodically reviewed, (3) some hazard analyses were incomplete or inaccurate, and (4) some hazards were not accurately communicated on warning labels as required. Arc flash hazards that have not undergone the required review, been updated, or were not accurately communicated on warning labels, could increase safety risk to personnel.

⁴ For Rutherford and Widows Creek, no hazard analyses or hazard calculation documentation was provided.

⁵ A condition report is a mechanism used to document an issue (undesired condition, problem, or concern raised by personnel).

Some Hazard Analyses Were Not Performed

TVA-TSP-18.1022 requires BUs to identify and analyze all electrical circuits and equipment with an arc flash exposure potential greater than, or equal to, 480 volts located within an arc flash boundary. In addition, OSHA requires employers to assess the workplace for flame and electric-arc hazards and states the employer must make a reasonable estimate of the incident energy to which the employee would be exposed.

During our evaluation, we were informed by TPS personnel that hazard analyses have not been performed for Bull Run⁶ and Widows Creek 500kV switchyards. TPS was also unable to provide documentation of hazard analyses for 34 of 53 500kV sites. Additionally, although TPS personnel initially informed us that high-hazard energy systems would be found at 500kV sites, we were later informed that hazard analyses have not been performed on high-hazard systems at some 161kV switchyards, such as Allen and Gallatin. Furthermore, TPS personnel acknowledged hazard analyses need to be performed for all open-air insulated lines and bus work.⁷

Hazard Analyses Were Not Periodically Reviewed As Required

TVA-TSP-18.1022 requires arc flash hazard analyses be reviewed periodically, not to exceed 5 years, to account for changes in the electrical distribution system that could affect the results of the arc flash hazard analysis. We determined hazard analyses were not periodically reviewed as required by procedure. TPS management personnel acknowledged hazard analyses were not being reviewed on a 5-year cycle and there is nothing currently in place to ensure reviews are performed timely.

Some Hazard Analyses Were Incomplete or Inaccurate

We determined 9 of 19 (47 percent) hazard analyses reviewed during our evaluation were incomplete or inaccurate, including:

- One was not updated after a major substation modification. TVA-TSP-18.1022 requires hazard analysis to be updated after major modifications have been made.
- One was not updated as of June 2021 after arc flash hazard calculations were updated in November 2020.
- Seven substations' arc flash hazard analyses did not match the hazard calculations provided. Three substations' hazard calculations had a higher incident energy level than the hazard analyses.

Hazard Analyses Were Not Accurately Communicated on Warning Labels

We determined there were missing and inaccurate warning labels that did not meet the requirements outlined in TVA-TSP-18.1022, *Arc Flash Protection*.

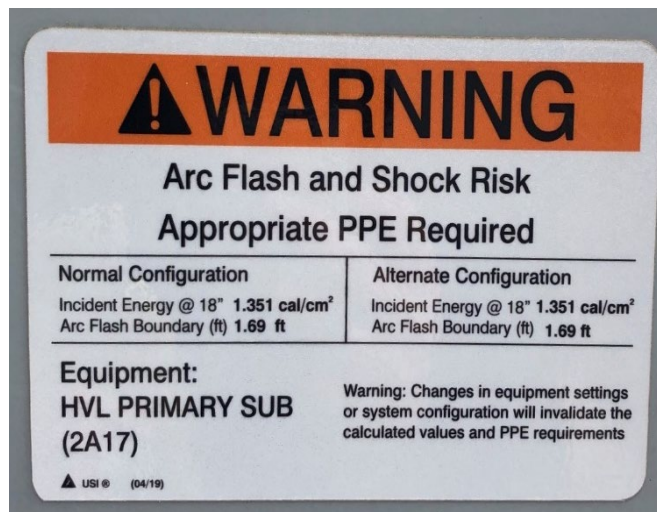
⁶ During our evaluation, we identified some hazard calculations from 2004 for Bull Run.

⁷ According to TPS personnel, open-air insulated lines and bus work are designed to use the insulating properties of ambient air as an external insulating medium. These are generally constructed in open, non-enclosed, and nonatmospherically controlled environments.

TVA-TSP-18.1022 requires posting of signs and labels on high-hazard energy equipment. In addition, OSHA regulation requires alerting techniques be used to warn and protect employees from hazards that could cause injury due to electric shock, burns, or failure of electric equipment parts. During our site visits, we identified missing and inaccurate labels at 3 of 6 sites, including:

- Four arc flash warning labels at Franklin 500kV had different incident energy information than was provided on the hazard analysis.
- Two arc flash warning labels at Franklin 500kV did not reflect the worst-case incident energy from the hazard calculations.
- Some high-hazard energy equipment was not labeled at Rutherford and Widows Creek 500kV sites.
- Widows Creek warning labels did not include shock hazard or PPE category ratings as shown in Illustration 3.

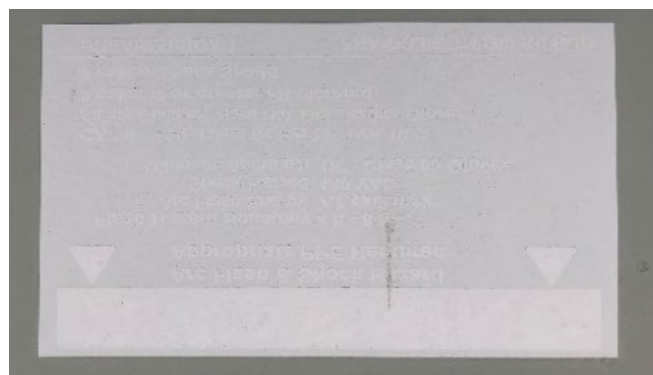
Illustration 3: Arc Flash Warning Label at Widows Creek 500kV switchyard.



In addition, Franklin, Rutherford, and Madison substations had faded warning labels whose legibility was limited as shown in Illustration 4. While we did not visit the site, we were also informed by TPS personnel there were no warning labels at the Bull Run 500kV switchyard.

Transmission Service Center managers indicated TPS personnel consult labels to determine arc flash hazards. When labels are missing or not accurate, employees could be at a greater risk of being injured.

Illustration 4: A faded Arc Flash Warning Label at Franklin 500kV substation.



HAZARD CALCULATIONS DO NOT MEET THE REQUIREMENTS OF THE ENGINEERING CALCULATIONS SPP

TVA-SPP-09.001, *Engineering Calculations*, requires calculation packages to (1) include a calculation coversheet (TVA Form 20156); (2) contain detail such as assumptions, special requirements, computations, and analyses; and (3) be signed and dated by a responsible manager. The SPP also requires all new or revised hazard calculation packages be entered into TVA's ECM.

Based on our review of the hazard calculations, we determined there were no documented signatures or dates of approval for 17 of the 19 site hazard calculations provided during our review. In addition, we determined 17 of the 19 site hazard calculations did not have calculation packages documented as described above or stored in ECM as required by TVA-SPP-09.001, *Engineering Calculations*.

Documenting and maintaining hazard calculations, as required, makes the arc flash hazards readily accessible for review and could reduce the risk of hazard errors.

MOST PERSONNEL COMPLETED REQUIRED TRAINING; HOWEVER, WE IDENTIFIED A FEW EXCEPTIONS

We determined most personnel who were assigned the arc flash training curriculum completed the training as required; however, we identified a few individuals who had not completed the assigned curriculum. TVA-TSP-18.1022 requires personnel who enter a defined and marked arc flash boundary to be trained to understand the specific hazards associated with arc flash.

Based on job codes and profile assignments, we identified 630 TPS personnel who should have been assigned the arc flash training curriculum. Our review of training records determined 614 (97 percent) had completed the initial curriculum as of November 30, 2020. We determined 7 of the 16 remaining employees were not assigned the curriculum in TVA's learning management system because their job codes had been removed from the curriculum.⁸ According to TVA personnel, and as a result of our evaluation, these job codes were subsequently reassigned the curriculum.

OPPORTUNITY FOR IMPROVEMENT

We identified an opportunity for improvement regarding an organization-specific arc flash procedure. Power Operations and TVA Nuclear have specific arc flash procedures related to their organizations; however, TPS does not. The lack of a TPS-specific arc flash procedure could have contributed to some requirements of TVA-TSP-18.1022, *Arc Flash Protection*, not being met. A transmission level SPP

⁸ According to TVA, the other 9 employees have since had the training requirement removed, completed the training, or been assigned the training.

could assign responsibilities, identify equipment and sites that require hazard analyses, and align TPS specific requirements with TVA-TSP-18.1022.

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Based on issues identified during the course of our evaluation, TPS performed an assessment of its arc flash program and developed an action plan to meet TVA-TSP-18.1022 and OSHA regulations. The actions planned include:

- Developing a TPS-level SPP, using other BU program documents as a guide, to align with TVA-TSP-18.1022.
- Developing substation and telecom engineering SPPs to align with a TPS level SPP that would standardize details and controls on how/when calculations are performed, documented, and maintained.
- Calculating arc flash energy and PPE levels for open-air insulated lines and bus work.
- Developing a resource plan, time period, and key performance indicators for addressing enclosed bus work sites.

RECOMMENDATIONS

We recommend the Senior Vice President, TPS:

- Determine if hazards analyses have been, or need to be, conducted for sites that have high-hazard energy.

TVA Management's Comments – TPS agrees with this recommendation and is in the process of reviewing all TPS sites to identify which ones require arc flash hazard analyses. See the Appendix for TVA management's complete response.

Auditor Response – We concur with TVA management's planned actions.

- Conduct periodic reviews as required by TVA's *Arc Flash Protection* procedure and verify hazard analyses are complete, accurate, and reflective of current operating conditions.

TVA Management's Comments – TPS agrees with this recommendation. A control measure will be used to ensure periodic reviews occur to the cadence outlined in TVA's *Arc Flash Protection* procedure. See the Appendix for TVA management's complete response.

Auditor Response – We concur with TVA management's planned actions.

- Verify warning labels are placed on hazardous equipment and meet requirements.

TVA Management's Comments – TPS agrees with this recommendation. TPS is in the process of implementing a plan to evaluate and make arc flash

warning labels legible. The warning labels will be updated, as needed, as hazard analyses are updated. See the Appendix for TVA management's complete response.

Auditor Response – We concur with TVA management's planned actions.

- Verify arc flash calculations are recorded in ECM as required.

TVA Management's Comments – TPS agrees with this recommendation and plans to include this as a requirement for hazard analyses moving forward. See the Appendix for TVA management's complete response.

Auditor Response – We concur with TVA management's planned actions.

- In coordination with Technical Training, review the list of job codes assigned the arc flash curriculum training for completeness and accuracy.

TVA Management's Comments – TPS agrees with this recommendation and is currently performing this review. See the Appendix for TVA management's complete response.

Auditor Response – We concur with TVA management's planned actions.

- Continue planned actions to develop a TPS-specific SPP to align with TVA's *Arc Flash Protection* procedure.

TVA Management's Comments – TPS agrees with this recommendation and is currently drafting a TPS SPP. See the Appendix for TVA management's complete response.

Auditor Response – We concur with TVA management's planned actions.

July 28, 2021

David P. Wheeler, WT 2C-K

REQUEST FOR COMMENTS - DRAFT EVALUATION 2020-15768 - TRANSMISSION AND
POWER SUPPLY ARC FLASH PROTECTION

Thank you for the opportunity to review and respond to the subject draft report, Transmission and Power Supply (TPS) Arc Flash Protection, provided on June 28, 2021. We also thank Kristin Leach for her diligence and support to improve the Transmission Arc Flash Protection Program.

TPS has reviewed the report and agrees corrective actions are necessary. Due to the serious nature of the identified gaps, we are already taking action in several areas, including the installation of temporary warning labels in the field over the coming months as a temporary mitigation while longer term corrective actions are enacted.

TPS is confident our planned corrective actions adhere to the *TVA-TSP-18.1022 - Arc Flash Protection* procedure and help maintain a safe work environment for our employees. The details of these actions are described below as they relate to the OIG's recommendations.

Recommendations

1. Determine if hazard analyses have been, or need to be, conducted for sites that have high-hazard energy.

TVA Response

TPS agrees with this recommendation. We are in the process of reviewing all TPS sites to identify which ones require arc flash hazard analyses. Work to perform analyses will begin immediately.

2. Conduct periodic reviews as required by TVA's *Arc Flash Protection* procedure and verify hazard analyses are complete, accurate, and reflective of current operating conditions.

TVA Response

TPS agrees with this recommendation. Following the above hazard analyses effort, a control measure will be used to ensure periodic reviews occur to the cadence outlined in TVA's *Arc Flash Protection* procedure.

3. Verify warning labels are placed on hazardous equipment and meet requirements.

TVA Response

TPS agrees with this recommendation. We are in the process of implementing a plan to evaluate and make legible the arc flash hazard warning labels for known sites with in scope enclosed systems. These warning labels will again be updated, as needed, as hazard analyses are updated.

David P. Wheeler
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4. Verify arc flash calculations are recorded in ECM as required.

TVA Response

TPS agrees with this recommendation and plans to include this as a requirement for hazard analyses moving forward. Arc flash hazard calculations will be recorded in ECM for each site as part of the hazard analyses update effort.

5. Continue planned actions to develop a TPS-specific SPP to align with TVA's *Arc Flash Protection* procedure.

TVA Response

TPS agrees with this recommendation. We are currently drafting a TPS Standard Program and Process document.

6. We recommend the SVP, TPS, in coordination with Technical Training, review the list of job codes assigned to the arc flash curriculum training for completeness and accuracy.

TVA Response

TPS agrees with this recommendation and is currently performing this review.

In summary, we agree with all of the OIG's recommendations and have initiated corrective actions which will be tracked through the TVA Corrective Action Process using CR #1708576. Accordingly, we submit this memorandum as our notice of acceptance of the recommendations and our initial corrective action plans. If you have further questions, please contact Tim Willis at 423-847-0729.



Aaron Melda
Senior Vice President
Transmission & Power Supply

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OIG File No. 2020-15768