Causal Analysis Report for Occurrence NA-SS-SNL-8000-2018-0002

Date: August 7, 2018

1. Report Number: NA-SS-SNL-8000-2018-0002

2. Subject/Title of Report: Electrical shock: Wind Turbine Nacelle, Lubbock TX

3. Responsible Manager (RM):

Amy Halloran, Senior Manager 8820

4. Causal Analyst and Type of Analysis Performed:

Causal Analyst Team

- Emily Wright, Senior Causal Analyst, Lead Analyst
- Cynthia Backlund, Senior Causal Analyst
- Marc Williams, Assisting trained causal analyst
- Greg Welch, Assisting trained causal analyst

Methods of Analysis

- Timeline analysis
- Change Analysis

5. Tech Area (Plant Area): Other **and System/Building/Equipment:** Scaled Wind Farm Technology (SWiFT) facility at Reese Technology Center in Lubbock, TX

6. Description of the Event

6(a). Short Description of Event: At 1:45 pm MST on June 11, 2018, a Sandia National Laboratories member of the workforce (MOW) reported feeling a contact, described as a tingling sensation, with electrical energy to the left thumb and first finger while working on an oil filter pump electrical system in the a1 wind turbine nacelle at SWiFT.

6(b). Event Narrative:

Issue Statement: A Sandia National Laboratories Member of the Workforce (MOW) experienced contact with electrical energy while performing work on an oil filter pump electrical system in the a1 wind turbine nacelle at Sandia National Laboratories Scaled Wind Turbine Facility (SWiFT).

The Department of Energy (DOE) Sandia National Laboratories (SNL) Scaled Wind Farm Technology (SWiFT) facility does research and development (R&D) work in collaboration with Texas Tech University. The SWiFT facility includes three turbines for performing wind plant and turbine technology research in support of DOE's Wind Energy Technology Office. The current work ongoing at the site is primarily related to commissioning the three turbines to support ongoing DOE customer needs and requests. It was during the performance of commissioning tests of the hydraulic systems in the a1 turbine that a Sandia MOW experienced contact with electrical energy.

There were multiple root and contributing causes that ultimately resulted in the electrical energy contact. These causes are summarized and aligned to their corrective actions in the

corrective action plan table provided in Section 7(c). The purpose of this narrative section is to provide additional information and context.

Narrative

Prior to the electrical energy contact, the MOW performed a lock-out tag-out (LOTO) procedure that removed power to the motors which turn the turbine nacelle to face the wind direction (referred to as the Yaw system) but does not remove power to the other turbine subsystems. The subsystems, separate from the Yaw system, have power provided by a second 480V power breaker. The Yaw system LOTO procedure is one of two approved SWiFT LOTO procedures. The second approved LOTO procedure de-energizes the entire wind turbine including lights and power needed to open nacelle roof-doors. The MOW did not use this second LOTO procedure. There was not a LOTO procedure more limited in scope and designed specifically for de-energizing power to the other turbine subsystems which are routed through a power box located in the nacelle of the wind turbine which has both 480V and 120V electrical contact points.

During execution of the commissioning process related to testing the hydraulic system, several errors surfaced and the Sandia MOW was in the process of replacing a non-functional component when the electrical contact occurred. The Sandia MOW believed that the nacelle power box had been de-energized. The Sandia MOW in the nacelle located at the top of the turbine used a hand-held radio to ask a Texas Tech MOW supporting operations at the bottom of the turbine to turn off the power. However, the Sandia MOW's verbal directions did not specify a specific switch. The Texas Tech MOW had placed a disconnect switch at the bottom of the tower in the off position in response to the Sandia MOW's request. The switch placed in the off position was labelled "480 V TOP TRANSFORMER" but was not the switch that supplied power to the nacelle 480V power box. The power box in the nacelle was not labeled to indicate that there are multiple sources of power including two 480V sources and one 120V source.

A zero-energy verification was conducted by the Sandia MOW at the top of the turbine in the nacelle. The MOW tested bus bar locations believing they were the source of incoming power but did not understand that multiple sources of power existed. Testing the bus bar and not each electrical contact was the MOW's familiar industry practice. In industry, maintenance work is done on multiple systems at one time to limit the number of climbs and time necessary to maintain systems. Rather than testing each electrical terminal for zero energy (Sandia expectation), which could include many electrical contact points, the bus bar supplying power to each of the terminals is measured to confirm zero energy (industry practice). This differs from Sandia's more comprehensive practices which includes checking every point of physical contact.

The MOW's screwdriver contacted a terminal that the MOW believed was not energized but had not been directly measured for zero energy. The screwdriver contacted the terminal and provided an electrical path through the screwdriver shaft into MOWs left thumb and finger. Immediately following the electrical contact, the Sandia MOW used a hand-held radio to inform the Texas Tech MOW at the tower bottom of what had occurred and that they were able to descend the turbine. The Texas Tech MOW then placed the main controller power switch into the off position to de-energize all power sources. The Sandia project lead went to the turbine upon hearing the hand-held radio communication. After the Sandia MOW descended the

turbine, personnel decided to maintain the scene as is for event and fact-finding purposes and to take the Sandia MOW to a medical facility in accordance with Sandia requirements.

The Sandia MOW performing the commissioning work has significant wind farm industry experience and was not sufficiently aware of the differences between operating the turbines in a research and development mode. The SWiFT facility operations differ from industry in that the turbines have nonstandard equipment that are maintained and tested. Also, the system design included multiple power sources which is a departure from industry standards. Significant differences in the Sandia LOTO requirements include performing a LOTO for this kind of work and for only operating under the lock of a person performing the work. That requirement would have been difficult to implement because the physical lock point for the 480V side of the power box is at the bottom of the turbine tower and roof-door controls are located at the top of the nacelle from the 120V circuits of the power box. Opening of the roof-doors is necessary because the nacelle ceiling is approximately five feet and opening of the doors allows for better movement (ergonomics), temperature control, and additional lighting. Locking out power, as expected by Sandia requirements, would require two climbs, one to go to the top of the tower and open the roof-doors followed by a descent to turn off power and place the lock and a second climb to perform the work. Climbs are done in full fall protection and self-rescue gear, which weigh just over 40 pounds, up a ladder to a height of approximately 100 feet. In industry there would only be one 480 V cable supplying power to the turbine nacelle power box.

The original turbine design, like what would be expected in industry, had one 480V power cable. In 2014 there was a significant safety event where a wind turbine blade was thrown following an uncontrolled free spin condition. Largely because of the 2014 event, SWiFT was classified as a Moderate Hazard Facility because of the potential for a thrown blade to have impacts beyond the boundaries of the SWiFT site. This change in facility designation invoked safety basis conduct of operations requirements and formal readiness review processes. The separation of the cable was one of several design changes introduced after the 2014 safety event where a blade was thrown from one of the turbines at SWiFT. This allowed workers to isolate the Yaw under a lock-out tagout mitigating pinch and crush hazards when climbing the turbine. In industry, the Yaw would be disabled by a switch located at the Yaw deck, however, the design team that developed the change had limited wind turbine industry experience. The team did not recognize that this change introduced potentially adverse conditions to turbine operations by adding unknown, or not well understood conditions. These conditions, and subsequent control requirements, were not identified because they were not evaluated with input from multiple environment, safety, and health technical subject matter experts during the creation of work planning and controls documents. In addition, configuration management practices lacked appropriate levels of formality as design drawings were not updated at appropriate intervals.

Some documentation of specific decisions made during the development of the Safety Assessment (SA) for the facility was not retained when the final document was completed. An SA is a required analysis, like a Documented Safety Analysis for a nuclear facility, and required for moderate hazard facilities. Supporting documentation, from key participants no longer employed at Sandia, was either lost or determined to not require retention. As such, it is difficult to reconstruct the specific basis for some of the decisions that were incorporated into the SA. Additionally, the scope of the SA went beyond the requirement of the Safety Basis

Manual (to address the hazard to the co-located worker), covering personnel safety issues such as fall protection, leading to a false reliance on the SA as having specifically addressed all hazards and identifying all appropriate activity level work controls.

Specific areas may or may not have been identified during the creation of the work planning and controls package but were not sufficiently communicated to the subsequent site team. These specific areas include identification of electrical energy and controls of that energy when commissioning, testing, and operating the turbines in a research and development environment. The need for a LOTO procedure for controlling the systems powered by the second 480V power line was not identified and therefore an appropriate procedure had not been created. It was also not recognized that there would be work performed within 12 inches of exposed live parts. The commissioning process tests each of the subsystems and workers executing the process expect to come across conditions that require troubleshooting. However, the commissioning procedure does not specifically address troubleshooting conditions and the need for a standalone troubleshooting procedure for working on energized systems had not been identified nor created.

Multiple changes and reductions in personnel while simultaneously doing research, construction, and operations created conditions in which the work planning and control inadequacies were not obvious. After the 2014 event, SWiFT was categorized as a moderate hazard facility invoking conduct of operations requirements. To meet these requirements a complex set of administrative paperwork, including the SA, was created. The complexity of the conduct of operations and readiness review processes and documentation required for the moderate hazard designation created a large learning curve for current site operational staff and management. The sheer volume of documentation created for conduct of operations and turbine commissioning readiness review created a belief that all work planning and controls requirements had been met. The conduct of operations packages had largely been developed by prior site personnel with the aid of safety basis and a wind industry technical review board. The lack of additional discipline-specific input from ES&H subject matter experts from areas such as industrial hygiene and electrical safety created missed opportunities to identify more clearly the ties between conduct of operations and work planning and controls requirements. Additionally, the SA went beyond the scope of the safety basis manual creating an overly complex documentation system and an overreliance on the Safety Assessment for worker safety (activity level work). This system, set up by personnel supporting operations after the 2014 event, had not been adequately transitioned to new support personnel in either responsibility or knowledge of intent of the documentation.

Multiple changes in management, project managers, site personnel, and ES&H support personnel created knowledge transfer inadequacies. The reasons for the configurations of the wind turbines and their subassemblies, specifically when they deviate from industry wind farm standards, were not known by current management and staffing, and were not adequately documented. The safety impacts of these deviations were also not adequately understood. Although the ES&H coordinator and management visited the site on multiple occasions to perform management surveillance walkthroughs, the work planning and control deficiencies previously discussed were not identified. The ES&H coordinator, who supported operations for several years and documented each of these surveillances, was likely not able to identify

inadequacies, potentially due to a mismatch in a radiation protection and cyber security background to actual site hazards and assurance processes at SWiFT. This ES&H coordinator abruptly left Sandia in April 2018 and was not able to provide his perspective on this analysis.

Inadequate succession planning and budget constraints created conditions where multiple roles were filled by one person. SWiFT has recently added new personnel with wind industry experience. However, a lack of formality associated with orienting new personnel with Sandia specific requirements (e.g. training, LOTO, emergency response) contributed to this event. This was compounded by a prior project lead shutting down communications between team members and management and driving away personnel due to a domineering personality. The Texas Tech project lead and former ES&H coordinator distanced themselves from interactions with this person and a subsequent project lead left the position because of similar difficult working conditions. This situation once identified by the leadership chain was dealt with but not before significant knowledge and history had been lost.

6(c). Operating/Environmental Conditions of Facility at Time of Event:

Normal commissioning tests were occurring. The outside temperature was approximately 98 degrees Fahrenheit, typical for west Texas in June. Temperatures within the turbine and in the nacelle were likely hotter as the turbines are not air conditioned.

6(d). Immediate Actions:

1. Person who contacted the electrical energy was taken for medical evaluation at the hospital.
2. After running electrical shock protocol tests and observing for 8 hours, the person was released with confirmation that no injury was sustained.
3. The main power to the turbine was shut off before leaving the scene.
4. A voluntary work pause was put in place by site management.

6(e). Extent of Condition Review:

Broader work planning and controls issue

Issue Statement: The work planning and control approach for SWiFT did not adequately identify or mitigate significant safety conditions at the site.

During event discovery a larger work planning and controls issue at SWiFT was revealed. Examples of safety conditions not adequately identified or mitigated by operational site personnel or by supporting Environmental Safety and Health (ES&H) personnel include;

- Ergonomic conditions,
  Electrical work conducted on the 480V side of the nacelle power box, and
- Potential nacelle confined space requirements.

Other issues include;

- Errors in electrical drawings
- Subsystems that are not tested prior to installation,

- Training requirement identification and documentation,
- Emergency response protocols, and
- Safety software test case requirements that are not yet in place.

In addition, event discovery revealed that SWiFT's remote site (Lubbock, TX) further exacerbates the potential for communication issues and/or logistical delays in receiving appropriate levels of oversight (e.g. ES&H professionals, federal oversight, etc.).

If not addressed these conditions may contribute to injuries and other safety issues in the future. The actions to address these additional issues are included in Section 7 of this report on pages 12 and 13.

7. Cause Analysis Results

7(a). Date Critique meeting was performed:

Critique was performed on 6/12/2018

7(b). Documentation Reviewed:

Note: many of these documents are located in the SWiFT EiMS files and are access protected. If you need access to these files please contact Jonathan Berg or Geoffrey Klise.

SWiFT Operations Website

Hazard Analysis Documentation

Job Safety Analysis Documentation

Safety Assessments

Occurrence Report NA-SS-SNL-6000-2014-0002 Wind Turbine Damaged as Scaled Wind Farm May 6, 2014

Conduct of Operations Documents

LOTO Procedure Turbine Electrical Shutdown

LOTO Procedure Turbine Electrical Maintenance

SWiFT Qualification Program Document and Training Matrix

7(c). Corrective Action Development and Documentation:

See table starting on the next page.

Corrective Action Plan

Root causes related to the shock event

Fact(s)	Issue	(C#) Cause and Cause Code	(CM#) Compensatory Measure Action	Action Owner – Due Date	Long Term Corrective Action	Action Owner – Due Date
1. The SWiFT facility operations differ from industry in that the turbines have nonstandard equipment that is maintained and tested more frequently. 2. System design included multiple power sources which is a departure from industry-based expectations.	1. There were unknown or not well understood new conditions introduced into the operating environment that could have adverse effects.	1. Lack of multidiscipline ES&H input during the creation of work planning and controls package. A4B3C09 – Work planning not coordinated with all departments involved in task	1. Identify multidisciplinary ES&H team needed to support SWiFT ongoing operations, including but not limited to, industrial hygiene, ergonomics, environmental compliance, safety basis, pressure safety, fall protection, and electrical safety/LOTO.	Cynthia Backlund 9/9/2018	2. Review and revise applicable work planning and control, conduct of operations, and project specific procedures, and hazardous energy control procedure (i.e. LOTO) to address and mitigate any additional hazards or inadequately addressed hazards as determined by the assessment.	Geoffrey Klise (working with Cynthia Backlund) 8/5/2019
		2. Conditions may not have been evaluated adequately during the development of work planning and controls packages A4B3C11 – Inadequate work package preparation	3. Schedule and conduct site assessment with multidiscipline ES&H team and site personnel.	Cynthia Backlund 10/24/2018	4. Orientation for any new personnel for the site to indoctrinate site personnel and manager into the Sandia approach design and operational requirements and how they differ from industry. Additionally, lessons learned from the 2014 Blade event and this event will be included in the orientation content.	Jonathan Berg 12/28/2018
					5. Develop a 3- year assessment schedule to review mitigation strategy on at least an annual basis with the newly identified ES&H multidisciplinary team in consult with point of contact at the National Renewable Energy Laboratory (NREL).	Cynthia Backlund 11/8/2018
			6. Have Sandia Corporate Electrical Safety Subject Matter Expert, consulting with a Vestas wind turbine technical expert, evaluate if the industry practice adequately controls hazards associated with the Yaw deck.	Mark McNellis 11/8/2018	7. Revise site operations procedures or LOTO procedures to implement acceptable controls for the Yaw deck.	Jonathan Berg 8/5/2019
					8. If feasible design and install a switch to remove power to the Yaw deck (industry approach).	Brandon Davis 8/5/2019
		3. New support MOW has significant industry experience and followed practices learned in industry which do not translate to the more conservative approach used at Sandia. A3B2C04 – Previous success in use of rule reinforced continued use of rule A4B4C11 – Assignment did not consider worker's ingrained work patterns			See corrective action number 4	

Corrective Action Plan

Fact(s)	Issue	(C#) Cause and Cause Code	(CM#) Compensatory Measure Action	Action Owner – Due Date	Long Term Corrective Action	Action Owner – Due Date
3. Work was performed in troubleshooting mode without following a troubleshooting guide or procedure.	2. Do not have an energized work procedure for working within 12 inches of exposed live parts and 150 to 600 volts.	4. It was believed that a troubleshooting procedure in an R&D environment would lack the flexibility necessary to work on prototypes. Therefore, performance of this work relied upon skill of worker and trial and error. A5B2C01 – Lack of written communication	9. Reassess design of nacelle components to identify where hazardous energy exposures can be controlled through engineered design.	Mark McNellis 11/8/2018	10. Develop a troubleshooting procedure that includes the potential to plan and perform energized work.	Brandon Davis 9/9/2018
					11. Train personnel on troubleshooting procedure.	Brandon Davis 9/24/2018
					12. Implement design changes identified by the nacelle design assessment to allow functional operation of nacelle i.e. need for lights and door motors to be operational while other components are locked out for maintenance activities.	Geoffrey Klise 8/5/2019
4. LOTO was performed per approved procedures removing power to the Yaw.	3. Worker made mistake doing zero-energy verification by not verifying absence of voltage on the K460 contactor.	5. An appropriate LOTO procedure for the work performed had not been developed. A5B2C01 – Lack of written communication Also reference cause number 3	13. All workers who access the nacelle complete Sandia-specific LTO210 training and be certified in the new LOTO procedure(s) or work under LOTO Incidental Worker Authorization Form.	Geoffrey Klise 8/10/2018	14. Add all PHS required training to the SWiFT worker qualifications matrix, including Sandia-specific LTO210 training and certification to the new LOTO procedures.	Michelle Williams 9/9/2018
			See corrective action number 9		See corrective action number 12	
5. This did not remove power from the hydraulic system or other subsystems.	4. Unique electrical system design and installation prevented the appropriate LOTO procedure for the work to be done.	6. The electrical design and installation would require multiple climbs to implement application of a lock as expected by Sandia's LOTO program A1B5C02 – Operability of design/physical environment LTA			15. Consult with electrical safety SME to develop and publish an approved group LOTO procedure which implements an acceptable alternative method of applying a lock without multiple climbs.	Brandon Davis 11/8/2018
6. The Sandia support MOW asked a Texas tech MOW to throw a power switch to disconnect power.	5. The wrong power was thrown on the transformer cable and not the 480 V cable to the hydraulics and other sub systems except for Yaw.	7. Signs and warnings of multiple power sources were not present on the electrical 480 V power box. A2B3C07 – Marking/Labeling LTA	16. Label the 480V power box and the down tower electrical cabinet.	Brandon Davis 9/9/2018	17. Revise procedures and work execution checklists to reference electrical circuits using a descriptive word like "hydraulic" and a number reference to improve nature of communications.	Brandon Davis 2/6/2019
		8. Sandia MOW used a radio to tell Texas Tech MOW on the ground to shut off power to "the box" but did not specify "F-30" in the verbal directions. A5B4C03 – Correct terminology not used				
		9. F-30 is not labeled as F-30 it is labeled "controller". A2B3C07 – Marking/Labeling LTA			18. Improve labeling system for electrical circuit isolations by utilizing word descriptions in addition to numbers.	Brandon Davis 2/6/2019

Contributing Causes related to the shock event

Corrective Action Plan

Fact(s)	Issue	(C#) Cause and Cause Code	(CM#) Compensatory Measure Action	Action Owner – Due Date	Long Term Corrective Action	Action Owner – Due Date
7. The original turbine design had one 480 V power cable which powered all the various systems and subsystems. 8. There were multiple design changes introduced after the 2014 event where a blade was thrown from one of the turbines.	6. The power cable was separated to be able to isolate the Yaw under a lock-out tag-out to mitigate hazards when climbing the turbine. This design was a significant departure from industry which created a complexity in system.	10. Hazard analysis team composed of personnel from safety basis and site design team did not have a complete understanding of the effect of the change or how drastically it differs from industry. A4B5C04 – Risks/consequences associated with change not adequately reviewed/assessed	See corrective action number 1 and 3		See corrective action numbers 2, 4 and 6	
	7. Industry practice to disable Yaw via a switch at the Yaw deck was not employed.	11. Limited wind turbine industry knowledge from either safety basis or site design team at the time the splitting of the power cable was implemented. Design intent of the decision was to ensure that there was no possible way of operating the Yaw motors. A1B4C01: Independent review of design/documentation LTA	See corrective action number 5		See corrective action numbers 7 and 8	
9. Multiple changes and reductions in personnel while simultaneously doing research, construction, and operations.	8. There have been significant operational resource constraints.	12. Budgets have been low over the past few years so there have been resource hiring hesitations. A4B2C03 – Insufficient manpower to support identified goal/objective	**Justification for no action**- Budget decisions are made by DOE and outside of Sandia's control.			
	9. Multiple roles filled by one person, due to lack of staff retention. Isolation of job duties creates a situation where personnel are not cross trained or positions are not more than one deep	13. Inadequate succession planning. A4B4C07 – Too many concurrent tasks assigned to worker	19. **Action already taken:** Matrixed staff have been brought in from other departments and an additional job posting has been posted.	Geoffrey Klise 7/26/2018	20. Clearly identify the most important responsibilities of each role in a Roles & Responsibilities document	Geoffrey Klise 2/6/2019
			21. Acting ES&H coordinator will not fully transition role to new ES&H coordinator until all actions have been completed to allow better continuity.	Cynthia Backlund 8/10/2018	22. Create plan that identifies how personnel will be cross trained.	Geoffrey Klise 2/6/2019
					23. Create and maintain succession plan for known and likely personnel transitions.	Geoffrey Klise 2/6/2019

Corrective Action Plan

Fact(s)	Issue	(C#) Cause and Cause Code	(CM#) Compensatory Measure Action	Action Owner – Due Date	Long Term Corrective Action	Action Owner – Due Date
(continued from previous page) 9. Multiple changes and reductions in personnel while simultaneously doing research, construction, and operations.	10. Very complex set of administrative paperwork driven by conduct of operations required for Moderate Hazard facilities makes it difficult to keep up with by the one person who had assumed multiple roles.	14. System had been set up by previous personnel, but had not been transitioned to new owner effectively. A5B4C01 – Communication between work groups LTA	See corrective action number 19		See corrective action numbers 20, 22, and 23	
		15. Safety Assessment Document (SAD) and analysis went beyond the scope of the safety basis manual creating an overly complex documentation system and an overreliance on the SAD for worker safety (activity level work). A4B5C06 – Personnel / department interactions not considered			24. Review and adjust the scope of the SAD to align with the existing scoping requirements of the safety basis manual.	Geoffrey Klise (working with John Myers) 8/5/2019
	11. Operational support personnel have changed. Full transition of operational knowledge was incomplete.	16. Prioritized knowledge transfer to new personnel knowing that further attrition was going to occur (e.g., NRT and modal analysis). A5B4C01 – Communication between work groups LTA			See corrective action numbers 20, 22, and 23	
	12. A shutdown of communications and low morale further reduced ability to retain staff and reduced management's awareness of issues.	17. Domineering prior project lead (one person) created a difficult and non-collaborative atmosphere and caused multiple staff to leave the organization or reduce the scope of their work supporting the project to avoid interactions with this person. A3B3C03 – Individual justified action by focusing on biased evidence	25. **Action already taken:** The prior project manager left the organization. A new project lead and level one manger were hired with significantly improved management styles. This has improved morale and collaboration. Additionally, a new ES&H Coordinator, Senior manager and Director have also significantly helped to improve awareness of issues and healthier working conditions.	Amy Halloran 4/25/2018		

Corrective Action Plan

Fact(s)	Issue	(C#) Cause and Cause Code	(CM#) Compensatory Measure Action	Action Owner – Due Date	Long Term Corrective Action	Action Owner – Due Date
10. Site operations were experiencing scheduling pressure from the DOE customer.	13. Scheduling conflicts to complete the readiness review process.	18. Project team delayed readiness review after having overestimated actual preparedness for the review. A3B3C05 – Incorrect assumption that a correlation existed between two or more facts A4B3C08 – Job scoping did not identify special circumstances and/or conditions	See corrective action number 19		See corrective action numbers 20, 22, and 23	
		19. Rescheduling was further complicated by single point of contact from safety basis supporting other activities. A4B2C03 – Insufficient manpower to support identified goal/objective	26. Request an alternate/additional point of contact to support readiness review process completion.	Geoffrey Klise 9/9/2018		
11. Worker starts to work on the K460 contactor and contacts electrical energy with left hand.	14. Using screwdriver with right hand guiding it with left hand touching the metal screwdriver shaft, which contacted the “hot” power bus.”	20. Non-conductive tools not available at the site. A4B4C11 - Assignment did not consider worker's ingrained work patterns	27. Have electrical safety assess the need for industry common tools, such as insulated or non-conductive tools.	Mark McNellis 11/8/2018		
12. The hazard classification changes from a low hazard facility to a moderate hazard facility after the 2014 blade event.	15. Safety management programs were assessed in previous readiness reviews but the number of assessment categories limited the amount of focus that could be given to any one area such as electrical safety.	21. Previous readiness review activities may have given a false sense of confidence in sufficiency of work planning and control for activity level work. A3B2C03 – Too much activity was occurring and error made in problem solving A4B4C07 – Too many concurrent tasks assigned to worker	28. Provide feedback to Safety Basis and Line Management communicating that a staged approach to readiness review may have been more appropriate. Conduct of operations associated with activity level work should have been assessed before moving on to readiness review for turbine restart. A review that is too broad may not be deep enough	Jonathan Berg 9/9/2018	See corrective action number 24	
13. SFO requires Sandia to apply Conduct of Operations to high and moderate hazard facilities.						

Causes related to work planning and controls extent of condition

Fact(s)	Issue	(C#) Cause and Cause Code	(CM#) Compensatory Measure Action	Action Owner – Due Date	Long Term Corrective Action	Action Owner – Due Date
14. The primary focus of work onsite was to perform commissioning tests of each turbine system to evaluate how they were functioning to operate/control the turbine to produce electrical power.	16. Inconsistencies in the "as-builts" were identified during the commissioning process.	22. Errors in the electrical drawings. A1B3C01 – Design/documentation not complete	29. Review electrical drawings to identify errors.	David Mitchell 11/8/2018	30. Revise, release, and maintain new electrical drawings for each turbine that accurately reflect the as-built configurations.	Brandon Davis 12/8/2018
					31. Implement appropriate configuration management processes to ensure drawings and system design documentation is maintained and accurate 32.	Jonathan Berg 1/27/2019
	17. Error conditions are not always identified prior to installation for sub-systems that are prepped 6-8 months beforehand in Albuquerque.	23. The hundreds of connections associated with some sub-systems are not bench tested before installation. A1B4C02 – Testing of design/installation LTA	33. Wire and functional check all components/installations where feasible prior to installation in nacelle.	Michelle Williams 11/8/2018	See corrective action number 31	
15. Changing parameters within a listed safety software is allowable if there is a documented test case that is followed that describes both the conditions under which parameters can be changed and the process to restore the parameters to their original configuration.	18. It was not known if there were acceptable conditions where the practice of altering or bypassing the software parameters is acceptable practice.	24. A documented test case for commissioning has not been created. A1B3C01 – Design/documentation not complete	34. Identify and document the allowable conditions for changing parameters in the listed safety software during commissioning, testing, and maintenance activities.	Jonathan Berg 11/8/2018	35. Develop the test case procedure for use during commissioning, testing and maintenance, when parameters need to be altered based on known acceptable conditions.	Jonathan Berg 2/6/2019
16. Only three PHS required training courses are listed in the matrix table located in the SWiFT Personnel qualification program. (Rev 3). Others are listed in the document but are less obvious.	19. Site personnel are not always aware of all their training requirements.	25. Several PHS required courses are not reflected in the SWiFT worker qualifications matrix including ELC210. A6B1C02 – Training requirements not identified	36. Review PHS documents to identify all Sandia required training for site specific activities.	Michelle Williams 9/9/2018	See corrective action number 14	

Corrective Action Plan

Fact(s)	Issue	(C#) Cause and Cause Code	(CM#) Compensatory Measure Action	Action Owner – Due Date	Long Term Corrective Action	Action Owner – Due Date
17. Medical attention is delayed	20. Workers do not go to emergency room directly, but rather, to two urgent care facilities which turn them away because the first does not take workman's comp issues and the second has an inability to evaluate an electrical shock.	26. Workers did not perceive that the contact was an emergency as there was no visible injury and the worker shocked did not feel unwell. A3B3C02 – LTA conclusion based on sequencing of facts A4B3C08 – Job scoping did not identify special circumstances and/or conditions	37. Modify procedures and provide training to communicate that location of care has been established by management. In-the-moment decisions are unlikely to realize all implications of deviating from emergency response plan	Michelle Williams 9/9/2018	38. Execute emergency management and/or operational drills in coordination with relevant entities (e.g. TTU) at a reasonable interval.	David Mitchell 11/8/2018
18. Cannot stand in the nacelle without the overhead doors open.	21. Lack of clarity around confined space status specifically related to C7 alternate entry during LOTO	27. Evaluated in 2013 as a confined space and determined as a non-permit confined space, but electrical hazards were not considered by IH. A4B3C08 – Job scoping did not identify special circumstances and/or conditions	39. Finalize formal Confined Space evaluation (corporate IH Program)	Cynthia Backlund 11/8/2018		

Causal Analysis Report

8. Supporting Documentation:

Note: The excel file embedded below contains the raw information solicited through the timeline and change analysis conducted on July 10 and 11. This information was used to identify the many causes related to this event and its extent of condition which is captured in the corrective action tables in section 7. There will not be a word for word translation from the raw information in the file to the information captured in the table. This is because through the development of the table, multiple iterations were necessary to distill the information to identify the critical areas for action and to more clearly articulate the information.

Causal Analysis Workbook.xlsx

Causal Analysis Report

Causal Analysis Team:

Role	Name	Org
Responsible Senior Manager (RM)	Amy Halloran	08220
Level One Manager	Geoffrey Klise	08221
Project Lead	Jonathan Berg	08221
Site Supervisor	David Mitchell	08221
Sandia MOW	Brandon Davis	08221
Texas Tech MOW	Miguel Hernandez	TTU
Texas Tech Program Lead	Anna Thomas	TTU
Texas Tech ES&H Point of Contact	Monte Ferguson	TTU
Supporting ES&H Coordinator	Cynthia Backlund	08517
Line Electrical Safety SME	Marc Williams	08517
Sandia Field Office	Daniel Pellegrino and David Barber	SFO
Safeguards and Security Regulatory Support Program	Randy Castillo	09114
Lead Senior Causal Analyst	Emily Wright	0635
Supporting causal analysts	Cynthia Backlund- Senior Causal Analyst Marc Williams- Trained Causal Analyst Greg Welch- Trained Causal Analyst	08517 08517 02253
Provided input but not present at causal analysis		
Safety Software SME	Ann Hodges	09125
Project Engineer	Josh Paquette	08821
Safety Basis Point of Contact	Albert Bendure	0632
Corporate Electrical Safety SME	Mark McNellis	0622

Causal Analysis Report

10. Approval:

Responsible Manager: _____7 AUG 2018_____ (Sign and Date)

Amy Halloran **Organization: 08220**