Lessons Learned Quick Reference Guide

Lessons learned are a resource enabling industry to identify problems, find what works, document the process, and share with industry. The creation of a lessons learned document is a collaborative effort between NERC, the Regional Entities, and the registered entities. A successful lessons learned document clearly identifies the lessons, contains sufficient information to understand the issues, visibly identifies the difference between the actual outcome and the desired outcome, and includes an accurate sequence of events, when it provides clarity. This document provides a brief summary of the lessons learned published since 2015 and will be regularly updated as more are published. All lessons learned published since 2010 are currently available on the Event Analysis web page.

2022 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
3/9/2022	LL20220301	Bulk Power System Operations	Managing UFLS Obligations and Service to Critical Loads during an Energy Emergency	Due to the amount of load shed during Winter Storm Uri, entities found it difficult to rotate customer outages while maintaining service to critical loads and underfrequency load shed (UFLS) feeders. Simultaneously, the percent of system load connected to UFLS feeders created a risk of frequency overshoot and instability in the event of UFLS activation. **This LL is of primary interest to Transmission Owners, Transmission Operators, Distribution Providers, Reliability Coordinators, Balancing Authorities, Planning Coordinators**

2021 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
10/25/2021	LL20211001	General Processes	Pandemic Response	By the early 2000's, most entities had created business continuity plans (BCP) for various disaster scenarios, including a major pandemic, and had periodic scenario drills to practice these plans. The COVID-19 pandemic resulted in actual use of these plans early in 2020. The first time a plan is executed with a real-life situation, it can be expected that adjustments will need to be made, and

2021 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				lessons will be learned to improve the effectiveness of future pandemic response plans and possibly improve response to other scenarios contained within the BCP. **This LL is of primary interest to Transmission Operators, Generator Operators, Reliability Coordinators, Balancing Authorities**
8/6/2021	LL20210803	Communications	Loss of Monitoring or Control Capability due to a Software Version Mismatch	A couple of entities have experienced energy management system (EMS) outages due to a software version mismatch between the product development system (PDS), quality assurance system (QAS), and production system (production). **This LL is of primary interest to Transmission Owners, Reliability Coordinators, Balancing Authorities**
8/6/2021	LL20210802	Relaying and Protection Systems	Multiple Faults in Rapid Succession Contribute to Relay Misoperations Leading to Loss of Load	Four separate faults occurred in rapid succession in a bulk power substation as a result of weather-induced salt contamination. Relay misoperations in the presence of the faults resulted in loss of load. **This LL is of primary interest to Transmission Owners, Transmission Operators**
8/6/2021	LL20210801	Transmission Facilities	Insulator Flashovers Due to Combination of Salt Spray Deposits Followed by Light Rainfall Initiating Loss of Load	Multiple parallel insulators in a bulk power substation that had been exposed to salt spray during a tropical storm flashed over two and a half days later when light rain began to fall. The flash overs were attributable to dry band arcing. Relay misoperations in the presence of the flashover faults resulted in loss of load. **This LL is of primary interest to Transmission Owners, Transmission Operators**
5/4/2021	LL20210501	Bulk Power System Operations, Generation Facilities	Interconnection Oscillation Disturbances	An Interconnection-wide oscillation of approximately 0.25 Hz frequency propagated through the entire Eastern Interconnection

2021 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				This LL is of primary interest to Reliability Coordinators, Balancing Authorities, Generator Owners, Generator Operators
4/13/2021	LL20210401	Generation Facilities, Transmission Facilities, Bulk Power System Operations	Controlled Islanding due to Wildfire Event	A registered entity experienced a wildfire in a transmission right of way (ROW) on a critical transmission corridor. To enable the firefighters to use aerial suppression agents on the fire, the entity was requested to de-energize all the transmission lines in the corridor, forming an electrical island. The registered entity was able to successfully separate a part of the system in a controlled manner and was able to assist firefighters in controlling the fire effectively. **This LL is of primary interest to System Operators, Transmission Owners, Transmission Operators, Generator Owners, Generator Operators, Balancing Authorities**
3/29/2021	LL20210302	Transmission Facilities	Catastrophic Failure of 345 kV Oil Filled Metering Current Transformer in a Transmission Substation	A 345 kV substation line current transformer C-phase experienced a catastrophic failure and caused the current transformer (CT) to explode, sending a significant amount of bushing glass shrapnel throughout the switchyard and creating a fire in the switchyard. **This LL is of primary interest to Transmission Owners, Transmission Operators, Generator Owners, Generator Operators**
3/29/2021	LL20210301	Transmission Facilities	Battery Energy Storage System Cascading Thermal Runaway	A fire started in a Battery Energy Storage System (BESS), resulting remote alarm triggering at approximately 16:55 PST. The utility, the maintenance provider, and fire fighters responded to the site. At approximately 20:04 PST, an explosion occurred that injured several firefighters and significantly damaged the BESS. A comprehensive investigation of the event was performed that identified the cause of the fire as being a cascading thermal runaway event that was initiated by an internal cell failure within one battery cell in the BESS.

2021 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				This LL is of primary interest to Transmission Owners, Transmission Operators, Generator Owners, Generator Operators, Transmission Planners, Resource Planning
2/25/2021	LL20210204	Relaying and Protection Systems	Transient Induced Misoperation: Approach II (Loss of Protection during Severe Lightning Event)	System 1 and System 2 protection groups shut down as a result of a lightning-strike-induced fault at one terminal of a 345 kV transmission line. Neither System 1 nor System 2 local relay protection cleared the fault. The fault continued for over 1.5 seconds until protection at the remote terminals tripped as designed via time-delayed elements. **This LL is of primary interest to Transmission Owners, Transmission Operators, Generator Owners, Generator Operators, Reliability Coordinators**
2/25/2021	LL20210203	Relaying and Protection Systems	Transient Induced Misoperation: Approach I (Control Circuit Transient Misoperation of Microprocessor Relay)	Voltage transients were found to initiate protective relay digital inputs during close-in faults to a hydroelectric dam. The false inputs resulted in multiple powerhouse line protection misoperations and the unnecessarily tripping of hundreds of megawatts of generation. Due to the vintage of the equipment and a failure of the relay to properly log events, little data was initially available for troubleshooting. The powerhouse line relays at both the substation and powerhouse were owned and operated by the TOP but were connected to and powered by the GOP's control circuits and battery at the powerhouse. **This LL is of primary interest to Transmission Owners, Transmission Operators, Generator Owners, Generator Operators**
2/10/2021	LL20210202	General Processes	Root Cause Analysis Tools – Barrier Analysis	The entity was adding a source of backup power to their primary system operating center (PSOC). Considerable movement of people and materials in and out of critical infrastructure protection (CIP) controlled areas occurred as contract workers had to install equipment and route cable. The contract construction workers had

2021 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				background checks and had been trained on the access procedure. After several access violations had been noted, a work stand-down was declared, and security expertise from one of the entity's nuclear stations was contacted for consultation. The security consultant used Barrier Analysis to determine the effectiveness of access control and logging at the PSOC. The consultant found that shortcuts bypassing the expected path had been used to move material from an outside laydown area and that barriers that should have prevented this were ineffective. There were access procedure weaknesses identified as well. **This LL is of primary interest to Transmission Owners, Transmission Operators, Generator Owners, Generator Operators, Reliability Coordinators, Balancing Authorities.**
2/10/2021	LL20210201	General Processes	Root Cause Analysis Tools – Change Analysis	A transformer catastrophically failed after approximately 20 years of service. It was one of two nearly identical transformers operating in parallel to feed a large community. Protective relays responded appropriately, opening the station's 138 kV and 13.8 kV breakers (one each) to isolate the fault. Because there were two 138/13.8 kV transformers, one that failed and one that did not fail, the entity used Change Analysis to find the root cause of the failure. **This LL is of primary interest to Transmission Owners, Transmission Operators, Generator Owners, Generator Operators, Reliability Coordinators, Balancing Authorities.**

2020 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
11/12/2020	LL20201102	Communications	Loss of State Estimator due to Contradicting Information from Dual ICCP Clusters	The entity encountered an operational problem, causing the state estimator (SE) to become nonconvergent. An evaluation indicated that SE was failing upon opposing device status sent from independent dual ICCP clusters. **This LL is of primary interest to Transmission Owners, Reliability Coordinators, and Balancing Authorities.**
11/12/2020	LL20201101	Transmission Facilities, Bulk Power System Operations	Cold Weather Operation of SF_6 Circuit Breakers	When a SF_6 circuit breaker (CB) hits its critical low pressure, its fault interrupting capability can be compromised. Most TOs protect against this by either auto-opening the CB prior to reaching the critical low-pressure level or by blocking the CB from tripping (when it reaches the critical low-pressure level) and relying on adjacent CBs to open in the event of a fault (breaker failure mode). If this occurs across multiple locations, it can place the Bulk Electric System (BES) at additional risk since it weakens the overall topology of the system and can result in more facilities being removed from service to clear a fault. It also means that the contingencies modeled and studied in real-time contingency analysis (RTCA) studies may no longer be accurate, thereby potentially putting the BES in a less secure or unknown state. That condition occurred during the severe cold weather event that hit the upper Midwest region of North America on January 29–30, 2019. **This LL is of primary interest to Transmission Owners, Transmission Operators, Generator Owners, Generator Operators, Reliability Coordinators.**
10/6/2020	LL20201001	Transmission Facilities	Single Phase Fault Precipitates Loss of Generation and Load	A single phase to ground fault on a 400 kV transmission line in Southern England precipitated the loss of 1,878 MW of generation. This led to a frequency decline that resulted in a loss of 931 MW of load. This European event has lessons applicable in North America.

2020 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				This LL is of primary interest to Transmission Operators, Generator Operators, Balancing Authorities, and Reliability Coordinators.
7/30/2020	LL20200703	Relaying and Protection Systems	Lockout Relay Component Failure Causes Misoperation and Reportable Event	Unnecessary trips for nonfault conditions are problematic for any protective relay and can be particularly problematic for lockout relays. Lockout relays are typically used to isolate and hold BES electrical equipment out of service for extended periods of time to allow for visual inspection and typically result in the operation of multiple interrupting devices. Many lockout relay types require manual reset, meaning that field personnel must travel to the relay location, inspect, and perform switching to restore systems to service. The resulting extended abnormal operating condition of the system may put the reliability of the BES at risk. **This LL is of primary interest to Transmission Owners, Generator Owners, and Distribution Providers.**
7/30/2020	LL20200702	Relaying and Protection Systems	Verification of AC Quantities during Protection System Design and Commissioning	Failure to employ effective commissioning testing practices or effective quality checks of protection system designs when installing or modifying protection systems can lead to protection system misoperations. These can occur with all components of protection systems, but issues with voltage and current instrument transformer wiring regularly surface when protection system misoperations occur. Protection system misoperations have an immediate negative impact on the reliability of the bulk power system and may cause a significant increase in the magnitude and scope of a disturbance. It should be noted that this lessons learned document is an expanded version of the NERC lesson learned document titled "Verification of AC Quantities during Protection System Commissioning" that was issued on March 11, 2014. The document has been expanded to provide additional guidance based on events noted since 2014.

2020 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				This LL is of primary interest to Transmission Owners, Transmission Operators, Generator Owners, Generator Operators
7/10/2020	LL20200701	Relaying and Protection Systems	Mixing Relay Technologies in DCB Schemes	Multiple composite protection system misoperations have occurred on the Bulk Electric System (BES) as a result of mixing protective relay technologies at the remote terminals of directional comparison blocking (DCB) schemes. One of the most challenging mix of technologies is utilizing a relay system based on newer microprocessors (µP) at one terminal and an older electromechanical (EM) relay system at the opposite terminal (examples shown in the figures below). Utilizing different models of µP based relays at each terminal can also be problematic. Often, only one terminal of a DCB system is upgraded to µP based relays due to various reasons, including different ownership of terminals, budget constraints, and emergency replacements. Relay timing and directional coordination is critical in DCB schemes that may be overlooked when relay technology or relay models vary between terminals. **This LL is of primary interest to Transmission Owners.**
6/11/2020	LL20200602	Bulk Power System Operations	Preventing Energy Emergency Alerts	As several energy emergency alerts (EEAs) were issued over the course of several months, key items were identified that could have prevented the EEAs from being issued and, in some cases, prevented the BAs from unnecessarily shedding firm load to maintain system reliability. **This LL is of primary interest to Reliability Coordinators, Balancing Authorities, Generator Operators, Generator Owners, and Reserve Sharing Groups.**
6/11/2020	LL20200601	Bulk Power System Operations	Unanticipated Wind Generation Cutoffs during a Cold Weather Event	A registered entity experienced extreme cold weather January 29–31, 2019. Unplanned wind generation outages contributed to a maximum generation event, resulting in the entity calling on load

2020 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				management resources (including demand response, behind-the-meter generation, and voluntary reductions) to avoid using emergency power purchases. **This LL is of primary interest to Reliability Coordinators, Balancing Authorities, Transmission Operators, Transmission Owners, Generator Operators, Generator Owners, and Reserve Sharing Groups.**
4/14/2020	LL20200403	Communications	Loss of Automatic Generation Control During Routine Update	During a weekly automatic generation control (AGC) software update, a critical AGC task aborted at one of two fully redundant control centers, and the same critical task aborted at the other control center four minutes later. As a result, generation schedules could not be set, and area control error (ACE) could not be automatically calculated until the issue was resolved. The cause was a modified line of code. **This LL is of primary interest to Transmission Operators, Generator Operators, Balancing Authorities, and Reliability Coordinators.**
4/14/2020	LL20200402	Transmission Facilities, Relaying and Protection Systems	Protected Fault in a Transmission Substation	Electronic communications equipment utilized to transmit and receive information from the remote terminals of a transmission line automatically shut down within milliseconds when a bus fault occurred at one terminal of the line. Neither the primary nor the back-up relay protection cleared the fault. The fault continued for over four minutes. **This LL is of primary interest to Transmission Operators and Transmission Owners.**
4/14/2020	LL20200401	Transmission Facilities, Relaying and Protection Systems	Misoperation of 87N Transformer Ground Differential Relays Causing Loss of Load	Gaps in implementing a modification and subsequent commissioning processes led to the omission of neutral connections for three separate transformer neutral differential relays, ultimately causing three simultaneous misoperations and a subsequent loss of load.

2020 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				This LL is of primary interest to Distribution Providers, Transmission Owners, Transmission Operators, Generator Owners, and Generator Operators.

2019 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
12/17/2019	LL20191201	Generation Facilities, Transmission Facilities	Moisture Intrusion in Hermetically Sealed Metering Current Transformers	Three hermetically sealed oil-filled metering current transformers (CTs) were placed in service after being in open storage for several years. One failed after five weeks of service; another failed after 10 weeks. **This LL is of primary interest to Transmission Owners and Generator Owners.**
9/5/2019	LL20190901	Communications	Risks Posed by Firewall Firmware Vulnerabilities	A vulnerability in the web interface of a vendor's firewall was exploited, allowing an unauthenticated attacker to cause unexpected reboots of the devices. This resulted in a denial of service (DoS) condition at a low-impact control center and multiple remote low-impact generation sites. These unexpected reboots resulted in brief communications outages (i.e., less than five minutes) between field devices at sites and between the sites and the control center. **This LL is of primary interest to Reliability Coordinators, Balancing Authorities, Transmission Operators, Transmission Owners, Generator Operators, Generator Owners, and Distribution Providers.**
08/13/19	LL20190804	Transmission Facilities	Breaker Failure due to Multiple Reclose Attempts	During a 115 kV permanent line fault, a line breaker malfunctioned and reclosed into the fault eight times before failing internally, resulting in a bus differential lockout clearing all breakers on the 115 kV bus. After working with the manufacturer, it was determined

2019 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				that the issue was caused by maintenance being done on the breaker incorrectly. **This LL is of primary interest to Transmission Owners, Transmission Operators, Generator Owners, and Generator Operators.**
08/01/19	LL20190803	Transmission Facilities	Inadvertent CVT Fuse Removal on a Live Circuit	During planned maintenance work on a 230 kV circuit (Circuit A), CVT fuses for a parallel circuit (Circuit B) were inadvertently removed during isolation. The inadvertent removal of the fuses resulted in the subsequent removal of Circuit B from service by line protection operation and a load loss of approximately 382 MW. **This LL is of primary interest to Transmission Owners, Transmission Operators, Generator Owners, and Generator Operators.**
08/01/19	LL20190802	Transmission Facilities	RAS Unexpected Operation	An unexpected remedial action scheme (RAS) operation was triggered by an external physical action that initiated a large amount of generation rejection and automatic load shedding as programmed according to the RAS settings. **This LL is of primary interest to Reliability Coordinators, Balancing Authorities, Transmission Operators, and Transmission Owners.**
08/01/19	LL20190801	Communications	Loss of Monitoring or Control Capability due to Power Supply Failure	Several entities have experienced energy management system (EMS) outages due to power supply failure. **This LL is of primary interest to Transmission Owners, Reliability Coordinators, and Balancing Authorities.**
05/22/19	LL20190503	Communications	Telecom Provider Failure Induced Loss of ICCP from Regional Neighbors	A registered RC experienced a temporary loss of inter-control center communications protocol (ICCP) data feeds from their regional neighbors. This loss of connectivity was due to third-party telecommunications vendor equipment that experienced a

2019 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				malfunction. For the next nine hours, these data links were intermittently unavailable. There was no adverse effect on the Bulk Electric System. **This LL is of primary interest to Reliability Coordinators, Balancing Authorities, Transmission Operators, and Transmission Owners.**
05/22/19	LL20190502	Communications	Enhanced Alarming Can Help Detect State Estimator and Real-Time Contingency Analysis Issue	Several entities in the ReliabilityFirst (RF) Region have experienced state estimator (SE) or real-time contingency analysis (RTCA) outages that could have been mitigated more quickly with better alarming. **This LL is of primary interest to Transmission Operators, Reliability Coordinators, and Transmission Owners who operate a state estimator.**
05/22/19	LL20190501	Transmission Facilities	Automatic Capacitor Operations along Radial Feed Result in Load Shed	An unplanned 138 kV bus outage created a radial load pocket without voltage or thermal violations. Shortly after, automatic switching involving two capacitor banks resulted in low voltages below emergency levels. The RC directed the TOP to shed approximately 30 megawatts (MW) of load to restore voltages to acceptable levels. **This LL is of primary interest to Transmission Operators, Transmission Owners, and Reliability Coordinators.**
02/28/19	LL20190202	Generation Facilities Transmission Facilities	Substation Fires: Working with First Responders	Two substation fire events occurred that highlight the importance of having an incident response procedure and command structure. In the first case, a fire occurred due to an arc flash on a 12 kV feeder circuit breaker within an enclosed substation. Although the fire department was dispatched to extinguish the fire, the ability to respond to the substation fire was delayed. In the second case, a 160 MVA, 230 kV/35 kV Transformer high-side bushing failed in an outdoor substation resulting in multiple operations removing the

2019 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				transformer, a 230 kV bus, and three transmission circuits in a large metropolitan city. An incident command post was established across the street promptly on the arrival of utility and fire department personnel. **This LL is of primary interest to Transmission Owners, Generation Owners, and Distribution Providers.**
02/28/19	LL20190201	Generation Facilities Transmission Facilities	Current Drone Usage	Some entities have begun using unmanned aerial vehicles (UAVs), commonly called "drones," for various purposes, such as major storm damage survey, line repair, substation/switching station and line inspections, power plant inspections, wind farm, gas pipeline inspections, and security. Many transmission tasks currently done with helicopters can be completed by or supplemented with drones, resulting in reduced cost, increased safety, and more schedule flexibility. Additional uses and benefits are likely to develop through utilizing this emerging technology. **This LL is of primary interest to Transmission Owners, Transmission Operators, Generator Owners, and Generator Operators.**

2018 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
10/17/18	LL20181002	Transmission Facilities	Incorrect Field Modification and RAS Operation Lead to Partial System Collapse	During an outage to isolate a 500 kV line disconnect switch and install a temporary bypass to facilitate its replacement, the position of an auxiliary contact multiplier relay was incorrectly modified by field staff. This incorrect multiplier position enabled line stub bus protection, which misoperated due to the increase in flow despite there being no actual line fault. This incorrect multiplier position also prevented the remedial action scheme (RAS) from operating as designed for the loss of the respective 500

2018 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				kV circuit. The actuations resulted in separation of a large portion of the entity's system, load losses, generator trips, and islanding of a small pocket sustained by local generation. **This LL is of primary interest to Balancing Authorities, Reliability Coordinators, Transmission Operators, Transmission Owners, Generator Operators, and Generator Owners.**
10/02/18	LL20181001	Communications	Networking Packet Broadcast Storms	When a second network cable was connected from a voice over internet protocol (VOIP) phone to a network switch lacking proper settings, a packet broadcast storm prevented network communications from functioning, and supervisory control and data acquisition (SCADA) was lost for several hours. Broadcast storm events have also arisen from substation local area network (LAN) issues. **This LL is of primary interest to Balancing Authorities, Generator Operators, Reliability Coordinators, Transmission Operators, and Transmission Owners that own and operate an Energy Management System.**
08/07/18	LL20180802	Transmission Facilities	Firewall Failure After Time Limit Exceeded	Due to a firmware error, a firewall stopped processing network traffic without proper failover after an internal run-time limit was exceeded. This resulted in persistent remote terminal unit (RTU) communication issues. **This LL is of primary interest to Balancing Authorities, Generator Operators, Reliability Coordinators, Transmission Operators, and Transmission Owners that own and operate an Energy Management System.**
08/07/18	LL20180801	Communications	Loss of Substation Data Circuits to SCADA	While initiating a transfer of SCADA (Supervisory Control And Data Acquisition) from the company's alternate control center (ACC) to

2018 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				primary control center (PCC), an interruption of vendor-provided substation data circuits occurred that resulted in a temporary and partial loss of SCADA operating and monitoring capability for more than 30 minutes. **This LL is of primary interest to Balancing Authorities, Reliability Coordinators, Transmission Operators, and Transmission Owners.**
07/24/18	LL20180702	Transmission Facilities	Preparing Circuit Breakers for Operation in Cold Weather	After two sequential line faults, an entire substation and a 1,150 MW nuclear plant tripped off-line due to consecutive breaker failures during cold weather (4°F). **This LL is of primary interest to Transmission Owners, Transmission Operators, Generator Owners,** and **Generator Operators.**
07/24/18	LL20180701	Transmission Facilities	Risk of Internet Accessible Cyber Assets	An electronic access point connected to the internet from a low-impact facility for remotely accessing a capacitor bank was compromised by unauthorized internet users for seven months prior to discovery. **This LL is of primary interest to Transmission Owners, Transmission Operators, Generator Owners, Generator Operators, and Distribution Providers.**
06/05/18	LL20180603	Communications	Back Office EMS Support Tools Impact Real-Time Situational Awareness	Upon receiving a call from its RC about a particular contingency, a registered entity identified that half of the contingency lists in the energy management system (EMS) list were disabled. This was due to a back-office study where the contingency list control display was opened and modified, inadvertently impacting the contingencies being displayed in the real-time environment.

NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

2018 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				This LL is of primary interest to Transmission Operators, Reliability Coordinators, and Transmission Owners who operate an EMS with study/simulation capabilities.
06/05/18	LL20180602	Communications	External Model Data Causing State Estimator to Not Converge	Several entities in the Reliability*First* (RF) Region have experienced state estimator (SE) outages due to Inter-Control Center Communications Protocol (ICCP) data received from neighboring entities. Upon investigation, the topology of the neighboring system had changed but the receiving entities had not updated their representation so the ICCP data no longer matched with the older model. The SE was unable to converge (or solve). **This LL is of primary interest to Transmission Operators, Reliability Coordinators, and Transmission Owners who operate an EMS with study/simulation capabilities.**
06/05/18	LL20180601	Transmission Facilities	Loss of Communication to Multiple SCADA RTUs at a Switching Center	Grid operations lost communication with multiple substation remote terminal units (RTUs) when conditions allowed a pre-existing configuration error to express itself. The event that transpired had wide reaching impacts to both control center operations and field personnel. **This LL is of primary interest to Transmission Operators and Reliability Coordinators.**
03/06/18	LL20180302	Transmission Facilities	Breaker Failure Due to Trip Coil Polarity	A temporary phase-phase-ground fault occurred on a 115 kV line. A 115 kV line breaker at one end of the line was slow to operate. Breaker failure protection operated, which caused the remaining two 115 kV breakers of a three-breaker switching station to open. This left the switching station de-energized. The breaker that failed to operate utilized two trip coils. Onsite investigation indicated that both trip coils had been damaged when they were energized to trip the breaker.

2018 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				This LL is of primary interest to Generator Owners, Transmission Owners, and Distribution Providers.
03/06/18	LL20180301	Communications	State Estimator Outages Requiring Tuning/Calibrating EMS Settings	Several registered entities have experienced short SE outages due to the software solutions not converging. The entities began troubleshooting techniques to locate and remove possible erroneous data point inputs into the energy management system (EMS) to help the SE to solve. After these techniques failed, each of the entities reached out to their EMS vendor for assistance. **This LL is of primary interest to Transmission Operators, Reliability Coordinators, and Transmission Owners who operate a State Estimator.**
01/03/18	LL20180101	Communications	Inadequate Battery Configuration Management Damaged a Generating Station and Tripped an HVDC Conversion Station	Progressive voltage drops occurred on three-phase transmission lines between a multiunit generating station and an AC-DC conversion station for a major intertie. At the same time, all units at the generating station were without monitoring and half of the units were running without control and protection due to the loss of DC supply. **This LL is of primary interest to Generator Owners, Generator Operators, Transmission Owners, and Transmission Operators.**

2017 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
08/24/17	LL20170801	Transmission Facilities	Auxiliary Power Loss to STATCOM Leads to UVLS Operation	A voltage disturbance on the transmission system led to the loss of redundant auxiliary cooling system power sources for a static synchronous compensator (STATCOM), causing the STATCOM to trip. Both auxiliary cooling power supplies were fed from the same high-voltage substation. The loss of the STATCOM exacerbated a low-voltage condition on the transmission system. Undervoltage

2017 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				load shed (UVLS) relays on distribution feeders in the area tripped as a result of the low voltage, shedding 92 MW of firm load. **This LL is of primary interest to Transmission Owners, Transmission Operators, and Reliability Coordinators.**
07/11/17	LL20170701	Generation Facilities	Loss of Wind Turbines Due to Transient Voltage Disturbances on the Bulk Transmission System	Voltage disturbance events on the transmission system in Australia and Texas have highlighted concerns with voltage ride through and in some wind turbine control system parameters. **This LL is of primary interest to Balancing Authorities, Transmission Operators, Generator Operators, Generator Owners, and Reliability Coordinators.**
06/20/17	LL20170601	Generation Facilities	Generator Trip While Performing Frequency Response	Two generating units were responding to a large frequency excursion when they tripped off-line on low boiler furnace pressure. **This LL is of primary interest to Generator Operators, Generator Owners, Balancing Authorities, and Reliability Coordinators.**
05/16/17	LL20170503	Communications	Loss of SCADA Operating and Monitoring Ability	A registered entity's system control center and their commercial operations center experienced a temporary loss of SCADA operating and monitoring capability. As a result, the entity's state estimator and contingency analysis were rendered inoperable for a 50-minute time period. Loss of SCADA connectivity (e.g., monitoring and control) was also experienced with the entity's HVD/LVD substations and the RC. The incident was a result of telecommunication equipment for the SCADA system being inadvertently powered down while non-routine scheduled maintenance was being performed. **This LL is of primary interest to Balancing Authorities, Transmission Operators, and Transmission Owners that own and operate state estimators, and Reliability Coordinators.**

2017 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
05/16/17	LL20170502	Communications	Line Frequency Excursion Causes UPS Shutdown and Control Center Evacuation	A control center was evacuated due to automatic shutdown of transmission switching and generation dispatcher SCADA workstations and system operation center servers. This shutdown was caused by a frequency excursion on the primary source transmission line that was feeding the control center. **This LL is of primary interest to Transmission Operators, Transmission Owners, Balancing Authorities, Reliability Coordinators, Distribution Providers, Generator Operators, and Generator Owners.**
05/16/17	LL20170501	Communications	Loss of Monitoring Due to Authentication Software Update	During a scheduled test of updated SCADA/EMS authentication software on the backup control center, the entity experienced loss of remote monitoring and control that lasted for 51 minutes before full system recovery. During this time, RTU polling ceased, and the ICCP datalink to its neighboring TOP and RC was not operational. **This LL is of primary interest to Reliability Coordinators, Balancing Authorities, and Transmission Operators.**
04/12/17	LL20170401	Generation Facilities	Dispatched Reduction in Generation Output Causes Frequency Deviation	A process conflict occurred during a normal data transfer process that resulted in undesirable unit commitment outputs from a Balancing Authority's security-constrained economic dispatch unit commitment software. System operators intervened by identifying and blocking the undesirable dispatches; however, some of the instructions could not be blocked or overridden. This caused the Balancing Authority to experience a reduction in generation output that caused its area control error (ACE) and system frequency to deviate for almost 20 minutes. **This LL is of primary interest to Balancing Authorities, Generator Operators, and Reliability Coordinators.**

2017 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
03/14/17	LL20170302	Communications	Loss of State Estimator Due to Propagated Database Values With Invalid Data	The entity encountered an operational problem, causing the state estimator (SE) to become nonconvergent. As a result, the Real Time Contingency Analysis (RTCA) application stopped running. An evaluation indicated that the SE application had encountered invalid data referred to as NaN (not a number, or invalid number, resulting typically from a divide by zero). This created invalid results that were propagated through many of the SE calculations, causing the SE to fail. The NaN values were generated by the application. These values were manually overridden to temporarily correct the issue. **This LL is of primary interest to Reliability Coordinators, Balancing Authorities, Transmission Operators, and Transmission Owners that own and operate state estimators.**
03/14/17	LL20170301	Facilities Design, Commission, and Maintenance	Slow Circuit Breaker Operation Due to Lubrication Issues	In 2015 and 2016, a total of 19 circuit breaker fail-to-trip operations were reported through the event analysis process. Twelve of those events were slow-to-trip circuit breakers. **This LL is of primary interest to Generator Owners, Transmission Owners, and Distribution Providers.**

2016 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
12/06/16	LL20161202	Communications	SCADA System Software Design Flaw Prevented Processing of Alarms and Events	A SCADA system encountered an operational problem when a software design flaw prevented the application from processing alarms and events due to a character limit within the SCADA database. **This LL is of primary interest to Reliability Coordinators, Transmission Operators, Generator Operators, and Balancing Authorities.**

2016 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
12/06/16	LL20161201	Communications	Loss of ICCP – Local Control Center Notifications	The loss of ICCP connectivity at one entity's (Entity A) control center resulted in a loss of the state estimator at another entity's (Entity B) control center. **This LL is of primary interest to Reliability Coordinators, Transmission Operators, and Balancing Authorities.**
11/01/16	LL20161103	Communications	Loss of ICCP due to Database Sizing Issue	During a network model update, a problem was caused by a combination of the number of points being requested by the state estimator (STE) and the number of points available in ICCP. This problem initiated a failure of ICCP, which resulted in the inability to obtain reliable results from the STE and contingency analysis applications. **This LL is of primary interest to Reliability Coordinators, Transmission Operators, and Balancing Authorities.**
11/01/16	LL20161102	Communications	Failover Configuration Leads to Loss of EMS	Configuration settings of an entity's EMS applications and tasks caused unintended automatic failovers to backup EMS servers multiple times in a row. This set up a failover loop, hindering recovery efforts. **This LL is of primary interest to Reliability Coordinators, Transmission Operators, and Balancing Authorities.**
11/01/16	LL20161101	Communications	Redundant Systems May Not Cold-Start Unless Fully Intact to Prevent Dual Primary Operation	A system failure occurred during routine maintenance of critical IP network infrastructure. Due to redundancy present in the system, no significant service interruption was expected. **This LL is of primary interest to Reliability Coordinators, Transmission Operators, and Balancing Authorities.**
10/04/16	LL20161001	Relaying and Protection Systems	DC Grounds and AC Tied to DC Cause Multiple Relay Misoperations	A dc ground coupled with an ac voltage tied to the 125 VDC battery system caused false breaker status indications on a line relay. This resulted in a relay misoperation. Also, a high-speed

2016 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				auxiliary relay misoperated momentarily to introduce 125 VDC due to the extremely small air gap in the normally open contacts. **This LL is of primary interest to Generator Operators, Generator Owners, Transmission Operators, and Transmission Owners.**
08/30/16	LL20160801	Relaying and Protection Systems	Tie Line Relay Coordination	A loss of three 345 kV transmission lines occurred when a phase A to ground fault on one line resulted in a misoperation that tripped a second line. As a result of these two lines tripping, the third line was open-ended due to the station bus configuration. The misoperation was the result of not coordinating relay communications equipment outages due to equipment failure between the different organizations. **This LL is of primary interest to Reliability Coordinators, Balancing Authorities, Transmission Owners, and Transmission Operators.**
07/05/16	LL20160701	Communications	Unavailability of the Transmission Stability Limits Calculation Application	The transmission stability limits calculation application became unavailable twice during a five-hour period. The first interruption was for a period of two hours and the second for 30 minutes. During the time that the application was unavailable, the transmission stability limits were not updated, but thermal real-time limits and post-contingency limits were still available during that time. **This LL is of primary interest to Reliability Coordinators, Balancing Authorities, and Transmission Operators.**
06/14/16	LL20160604	Communications	ICCP Communication Failure Due to Firewall Patch Update	During a regularly scheduled firewall patch installation, a Transmission Owner experienced multiple inter-control center communications protocol communication failures with external entities.

2016 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				This LL is of primary interest to Reliability Coordinators, Balancing Authorities, Transmission Service Providers, Generator Owners, Generator Operators, Transmission Owners, and Transmission Operators.
06/14/16	LL20160603	Communications	Loss of Monitoring Capabilities Due to FEP Hardware Malfunction	An entity experienced a loss of monitoring capabilities at the primary control center and backup control center due to a front end processor (FEP) hardware malfunction. **This LL is of primary interest to Transmission Owners and Transmission Operators.**
06/14/16	LL20160602	Communications	SCADA Failover Event	While initiating a failover process between the entity's primary and secondary data source, supervisory control and data acquisition caused the system to come up in a paused state. This paused state created a temporary loss of generating management system functionality. **This LL is of primary interest to Transmission Operators, Balancing Authorities, Reliability Coordinators, Distribution Providers, and Generator Operators.**
06/07/16	LL20160601	Relaying and Protection Systems	Transmission Relaying - Relay Setting Issue	A line relay protecting a 230 kV line misoperated for a fault on a 115 kV line. The relay misoperation occurred due to the entity utilizing a manufacturer's automatic setting method based on line parameters. The relay misoperation resulted in the tripping of the two associated 115 kV low-side transformer breakers and the transfer tripping of the two remote terminal breakers of the 230 kV line. The line relaying on the faulted 115 kV line operated correctly. **This LL is of primary interest to Reliability Coordinators, Transmission Owners, and Transmission Operators.**

2016 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
05/24/16	LL20160501	Communications	Control Center Loss of SCADA Control and Monitoring Capability	An energy management system supervisory control and data acquisition group-control command was initiated to disable instantaneous relay trip settings for approximately 300 distribution feeder circuit breakers. This caused the application to abort and not restart, rendering SCADA unavailable for 67 minutes. **This LL is of primary interest to Balancing Authorities, Generator Operators, Generator Owners, Reliability Coordinators, Transmission Operators, and Transmission Owners.**

2015 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
12/29/15	LL20151203	Generation Facilities	Human Error Leads to Evacuation of Primary Control Room	A utility had to evacuate its primary control center due to smoke from a nearby fire that was caused by maintenance worker failing to follow proper hot work procedures. **This LL is of primary interest to Balancing Authorities, Transmission Operators, and Generation Operators.**
12/29/15	LL20151202	Communications	Control Network Communication Path	Following a failover exercise being conducted pursuant to EOP-008-1, the TOP’s router bandwidth for network traffic between control centers saturated and led to a flat-line condition, preventing communication between the active control center and the active data center. The active data center serves the active control center’s monitoring and controlling capability by housing the active supervisory control and data acquisition servers and associated equipment. As a result of the bandwidth saturation, the active control center lost the ability to monitor and control its portion of the Bulk Electric System for approximately 39 minutes. **This LL is of primary interest to Reliability Coordinators, Balancing Authorities, and Transmission Operators.**

2015 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
12/29/15	LL20151201	Bulk Power System Operations	SOL and IROL Monitoring Tool Leads to Unnecessary Manual Load Shedding	A breaker fault on a shunt reactor of a high-voltage transmission line caused the line to trip. This event led to the exceedance of two interconnection reliability operating limits. Immediate actions were taken to clear those exceedances within the required 30 minutes. However, the involved interfaces have both a system operating limit and an interconnection reliability operating limit. This caused the transmission system operator to misinterpret the information by not noticing that the flows were still above the system operating limits while the interconnection reliability operating limit exceedances were being addressed. Since the transmission system operator confused the two limits, the operator proceeded to manually shed load in an attempt to return the flows back to within what was believed to be interconnection reliability operating limit values but were really system operating limits. This occurred 28 minutes after the start of the event. **This LL is of primary interest to Reliability Coordinators, Balancing Authorities, and Transmission Operators.**
10/20/15	LL20151001	Communications	Loss of EMS Due to RTU LAN and UPS Failure	A temporary rack-mounted uninterruptible power supply failed, resulting in the loss of the remote terminal unit local area network, the loss of system visibility, and the failure of the inter-control center communications protocol link for 50 minutes. **This LL is of primary interest to Reliability Coordinators, Balancing Authorities, and Transmission Operators.**
09/15/15	LL20150902	Relaying and Protection Systems	Relay Design and Testing Practices to Prevent Scheme Failures	A single-phase-to-ground fault occurred on a 230 kV three-terminal feeder. All associated circuit breakers initially tripped. The line automatically reclosed at one end, re-establishing the fault. Although the protection schemes were fully redundant, because of the occurrence of two protection equipment failures, which were unrelated to each other, no tripping occurred after the automatic

2015 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				reclose. The fault evolved to a multi-phase-ground fault and persisted for a total of 58 seconds eventually clearing by backup ground protection on two 500 kV lines. Breaker failure protection was not initiated during this event. **This LL is of primary interest to Transmission Operators and Transmission Owners.**
09/15/15	LL20150901	Communications	Loss of EMS Communications Due to Lack of Validation on EMS Database RTU Configuration Parameter	An energy management system lost communication with some remote terminal units. **This LL is of primary interest to Reliability Coordinators, Balancing Authorities, Transmission Operators, and Transmission Owners.**
06/25/15	LL20150604	Communications	EMS Recovery Strategy	An energy management system auto-recovery process was configured such that all nodes (e.g., servers, workstations) in the system were prompted to reboot for a particular condition. This complete system restart sequence took 47 minutes to complete. Consequently, there was a complete loss of control and monitoring functionality until each critical server and workstation reported its status as normal and fully functional. **This LL is of primary interest to Reliability Coordinators, Balancing Authorities, Transmission Operators, and Transmission Owners.**
06/25/15	LL20150603	Bulk Power System Operations	Pre-Contingent Load Shed Event	During the planning process of an outage to remove a 345-kV circuit breaker from service for retrofit and maintenance, a cascading outage was identified and analyzed for conditions affecting generation and loading in the outage area. The Reliability Coordinator utilized the real-time contingency analysis tool to identify an overload on an adjacent system transformer that indicated a loss of a 345 kV line, which could cause the loss of any remaining 345 kV due to the bus configuration with the breaker out of service and could subsequently eliminate all 345 kV support in the substation.

2015 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				This LL is of primary interest to Balancing Authorities, Reliability Coordinators, Transmission Operators, Distribution Providers, and Load Serving Entities.
06/09/15	LL20150602	Generation Facilities	Generator Distributed Control System Impact on Automatic Voltage Regulators	The Reliability Coordinator and Transmission Operator within an RC footprint observed unusual generator reactive output following the switching of a shunt reactor near all of the generators' points of interconnection. **This LL is of primary interest to Reliability Coordinators, Transmission Operators, Generator Operators, and Generator Owners.**
06/09/15	LL20150601	Communications	Real-Time Contingency Analysis Failure due to a Modeling Error	A Real-Time Contingency Analysis process failed to converge for 46 minutes. **This LL is of primary interest to Reliability Coordinators, Balancing Authorities, Transmission Operators, and Transmission Owners.**
04/21/15	LL20150402	Transmission Facilities	Severe Flooding Damages Transformer Substations	Record rainfall within a metropolitan area caused severe localized flooding at two large transmission substations, quickly rendering the stations and all terminating circuits unavailable and damaging telecommunication, protection, and station service equipment. **This LL is of primary interest to Distribution Providers, Generator Owners, Generator Operators, Reliability Coordinators, Transmission Operators, and Transmission Owners.**
04/21/15	LL20150401	Relaying and Protection Systems	Detailed Installation and Commissioning Testing to Identify Wiring or Design Errors	During a recent event, problems were encountered regarding redundant relays associated with a remedial action scheme, where two redundant remedial action scheme input/output (I/O) devices failed due to a firmware RAM/ROM processor error. The device failure alarms went undetected because of an error on the wiring diagram that prevented the positive dc from being connected

2015 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				properly, thus disabling the signaling of the I/O device's alarm status. While the schematic (or elementary diagram) correctly showed the proper I/O device alarm circuit design and connections, the wiring diagram of the RAS panel did not match the schematic. **This LL is of primary interest to Generator Owners, Generator Operators, Transmission Operators, and Transmission Owners.**
03/03/15	LL20150302	Communications	Importance of State Estimator Save Cases and Troubleshooting Guide	A state estimator failed to solve for 37 minutes, resulting in real-time contingency analysis also being unavailable. **This LL is of primary interest to Reliability Coordinators, Transmission Operators, and Transmission Owners.**
03/03/15	LL20150301	Communications	Importance of Backup EMS Failover Testing After Network Device Reconfiguration	There was a loss of energy management system supervisory control and data acquisition functionality for 49 minutes during a scheduled transfer of the EMS from the alternate control center to the primary control center. **This LL is of primary interest to Reliability Coordinators, Transmission Operators, and Transmission Owners.**
02/10/15	LL20150202	Relaying and Protection Systems	Consideration of the Effects of Mutual Coupling when Setting Ground Instantaneous Overcurrent Elements	An event occurred that caused the unintended trip of a transmission line connected to a large generation facility. The transmission system and generation response to the loss of this line resulted in an unintended total loss of transmission connection to the generating facility. An investigation revealed that the unintended trip of the transmission line was due to an incorrect setting on a numerical relay directional ground instantaneous overcurrent element. This setting caused it to misoperate in response to a fault on a mutually coupled adjacent line. Failure to consider the effects of mutual coupling between adjacent lines led to the improper derivation of the ground

2015 Lessons Learned				
Date	**LL #**	**Category**	**Title**	**Summary**
				instantaneous overcurrent element settings, and this resulted in a protection system misoperation. **This LL is of primary interest to Generator Owners, Generator Operators, Transmission Operators, and Transmission Owners.**
02/10/15	LL20150201	Relaying and Protection Systems	Digital Inputs to Protection Systems May Need to be Desensitized to Prevent False Tripping Due to Transient Signals	A converter station was lost due to the erroneous initiation of a top-oil temperature trip signal from a transformer protection system. The operating entity investigated the connections in the transformer cabinet at the time and visually inspected the transformer and temperature gauges. Both the transformer's current temperature and the drag hand for the high-temperature indication were well below the alarm and trip levels. There was no evidence found to indicate any loose or corroded connections in the transformer cabinet. Multiple events initiated by this type of erroneous input signal have been observed in the event analysis process. **This LL is of primary interest to Generator Owners, Generator Operators, Transmission Operators, and Transmission Owners.**