Texas Reliability Entity, Inc.
Event Analysis

Event:
July 3, 2015
Lower Rio Grande Valley
Loss of Multiple Elements and Under-Voltage Load Shed (UVLS) Operation

September 16, 2015

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Executive Summary

On July 3, 2015 at 17:16, a horizontal post insulator failure on a 138 kV transmission line in the Lower Rio Grande Valley caused a multi-phase-to-ground fault. The line fell into the 138kV bus at the substation causing an A-phase-to-ground fault on the 138kV bus. The line also contacted 12 kV circuits at a nearby 69-12 kV substation. Multiple protection system misoperations and other sympathetic trips occurred to expand the scope of the outage. The most significant of these was the loss of a static VAR compensator (STATCOM) and capacitor bank at a nearby 138 kV substation. The loss of multiple elements created a low voltage condition in the local area on the transmission system which resulted in operation of Under-Voltage Load Shed (UVLS) relays in the area. Loss of firm load from the event was 95.5 MW of consequential load loss plus an additional 92 MW due to the UVLS relay operations. Additionally, 244 MW of wind generation tripped off after the initial fault. As different line energization attempts occurred over the next 15 minutes, multiple wind farms experienced additional turbine trips. Two other significant losses of wind generation occurred at 17:29 and 17:32 of 120 MW and 109 MW, respectively.

This report provides: (1) an overview of the event; (2) background on system conditions just prior to the event; (3) the detailed sequence of events; (4) an analysis of the causal and contributing factors for concerns that arose in this event; and (5) recommendations for follow-up action.

Observations and conclusions pertaining to the period of July 3, 2015 are:

(1) Contingencies used in Planning and Operations related to the STATCOM equipment: When the STATCOM tripped, it resulted in the additional loss of a 57.6 MVAR capacitor bank at the substation due to an interlock in the tripping circuit. The loss of this reactive support was a key factor in causing the low voltage condition on the transmission system.

(2) UVLS load restoration: Local transmission and distribution system operators indicated that they did not have SCADA indication that the feeders had tripped by UVLS relays. Operators restored these feeders within several minutes per their normal operating practices. ERCOT Operating Guides require entities to coordinate restoration of UVLS load through ERCOT.

(3) Generator voltage ride-though: Several wind generation facilities in the area had issues with individual wind turbines tripping offline during the transient voltage conditions that occurred due to the multiple fault events. Approximately 475 MW of wind generation tripped at various times during the event.

(4) Protection system performance: Multiple protection system misoperations occurred to expand the scope of the outage and the number of customers impacted.

(5) System Operator actions: Local transmission operators attempted to re-energize the faulted 138 kV circuit seven times in a ten-minute period before sectionalizing the line. Each attempt resulted in a 3-phase fault on the system due to the downed conductor.

Recommendations pertaining to the period of July 3, 2015 are:

(1) Transmission owners should review the design for the auxiliary power to static VAR compensators to ensure they will stay in service during low transmission voltage conditions.
(2) Transmission operators should consider adding a trip indication of its UVLS relays to SCADA for operator awareness as well as verify the correct operation of any existing indications.
(3) Wind generators should review their voltage ride-through settings to ensure the units remain on-line during transient voltage conditions. Impacts of low voltage event counters on wind unit operation should be examined and shared with the transmission operator.
(4) Local transmission operators should review the operation of reactive devices in an area that can lose a significant amount of reactive support after a single contingency. Review of criteria or guidelines for the amount of dynamic reactive capability available (reserve requirement) should be considered.
(5) End-use Customer Demand Loss: A large amount of end-use customer load was lost during the event that was not due to the UVLS relays tripping or due to the transmission line outages. The reason(s) for this load loss needs to be understood and included in future planning assessments, UVLS design, and operational settings for dynamic reactive support devices.

I. Event Overview

On July 3, 2015 at 17:16, a horizontal post insulator failure on a 138 kV transmission line in the Lower Rio Grande Valley caused a 3-phase-to-ground fault as the conductor moved around. The transmission line fell into the 138kV bus at the substation causing an A-phase-to-ground fault on the 138kV bus. The line also contacted 12 kV circuits at a 69-12 kV substation. Multiple protection system misoperations and other sympathetic trips occurred to expand the scope of the outage. This most significant of these was the loss of the STATCOM and capacitor bank at a nearby substation. The loss of multiple elements created a low voltage condition in the local area on the transmission system which resulted in operation of UVLS relays in the area.

For the purposes of this report, the event began at 17:16:41 when a post insulator failed on the 138 kV circuit. The phase conductor fell across an adjacent conductor resulting in a phase-to-phase-to-ground fault. Circuit breakers operated to clear the initial B-phase to C-phase to ground fault, then reclosed when the fault resumed as a 3-phase to ground fault. A misoperation of the protection system on an interconnected 138 kV circuit resulted in a single-end trip. The fault condition also resulted in the trip of the STATCOM and capacitor bank due to low transmission system voltage.

Approximately two seconds later at 17:16:43, the phase conductor fell across the 138 kV bus at the substation, creating an A-phase-to-ground fault. Bus differential relays

operated to clear the bus. A misoperation of the protection system on an interconnected 138 kV circuit resulted in a single-end trip.

The faults on the transmission system and the loss of the STATCOM and capacitor created an extended low voltage condition in the area. UVLS relays at seven substations operated to trip their loads. These relays were all set at 85% of nominal voltage with a two second time delay.

At 17:22, the failed conductor fell across several 12 kV distribution circuits at an adjacent 69-12 kV substation which was located directly adjacent. This resulted in faults on these circuits and the failure of the 69-12 kV transformer at the substation.

Between 17:23 and 17:33, System Operators tried multiple times to re-energize the failed 138 kV circuit. Each attempt resulted in a three-phase fault on the system due to the downed conductor. At 17:33, the failed 138 kV line segment was sectionalized and one segment of the line was re-energized from the remote end.

The 138 kV bus was restored on July 4, 2015 at 00:24. The failed 138 kV line segment was restored at 00:58.

On July 3, 2015, the Valley load was approximately 1948 MW at the time of the event. Between 17:16 and 17:18, approximately 45,000 separate customers were affected as a result of the consequential load loss and UVLS relay operations. Telemetry data shows a loss of demand totaling 317 MW (16.3% of the total Valley load). UVLS relay operations and load loss consequential to the loss of the transmission equipment account for 187.5 MW (9.6% of the total Valley load) and end-use customer demand loss accounts for the remainder. See Figure 1 and Table 1.

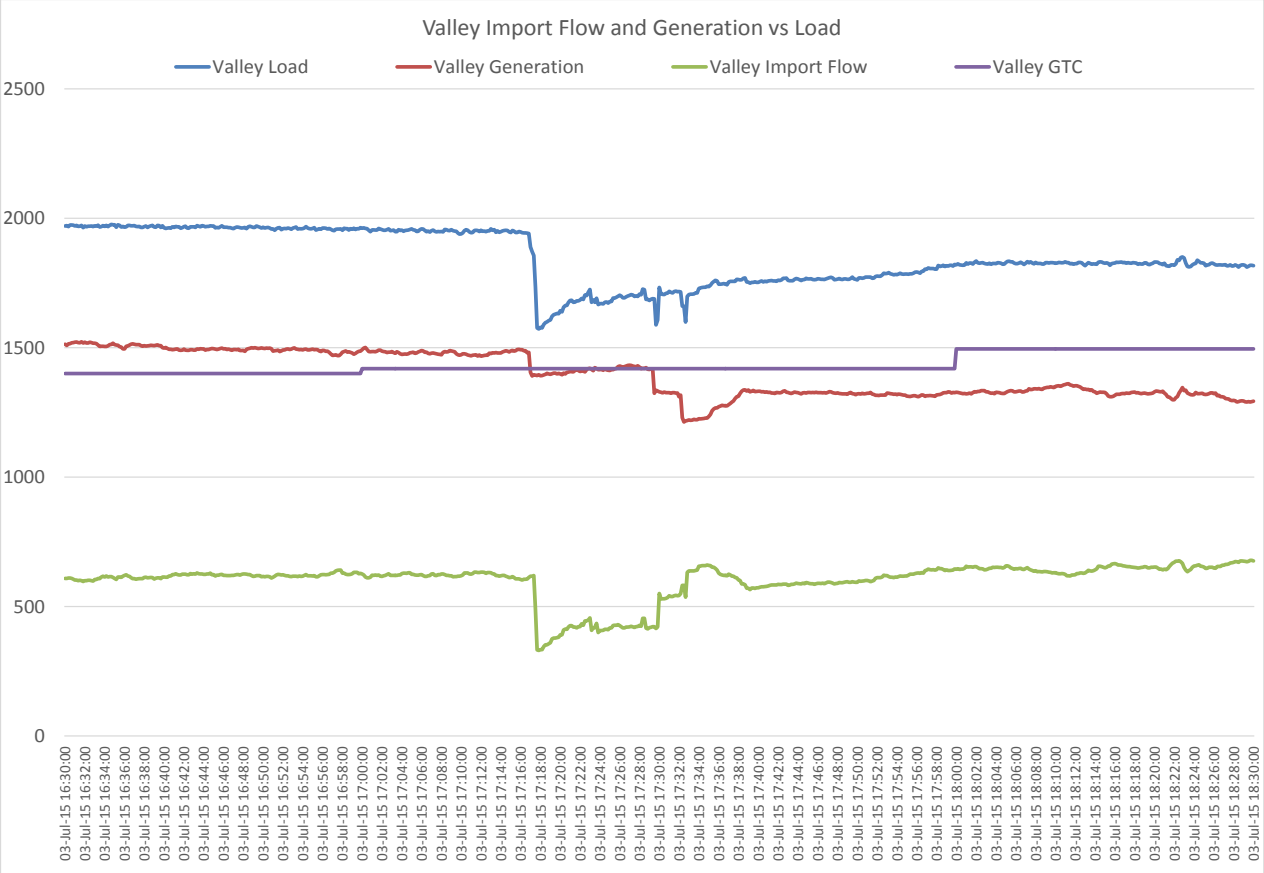

Figure 1: Valley Import Flow, Demand, and Generation

	Customers Affected	MW Load
UVLS	23,921	92.04 MW
Consequential load loss from transmission line outages	21,139	95.5 MW
Other/End-Use Customer	Unknown	129.5 MW
Total	45,060	317 MW

Table 1: Customer Impact from Event

The event met the criteria for North American Electric Reliability Corporation (NERC) Event Reporting under NERC Reliability Standard EOP-004-2 and was a Category 1a(i) reportable event under the ERO Events Analysis process due to the unexpected loss of three or more Bulk Electric System (BES) elements, contrary to design, caused by a common disturbance.

II. Initial System Conditions Prior to Event

Initial system conditions just before the event at July 3, 2014 17:00 were:

Active Forecast Peak HR Demand:	56,260 MW @ 1700 HR
Actual load at time of event:	54,308 MW @ 17:15
Load Shed Risk:	Low @ 1500 HR
Valley Net Generation:	1485 MW @ 1715
Railroad DC Tie Flows:	-150 MW @ 1715
Valley Area System Load:	1948 MW @ 1715

Weather in the major cities around the ERCOT region just before the event:

City	**Temp (F), High/Low**
Austin	91/72
Brownsville	92/75
Corpus Christi	91/77
Dallas	92/78
Houston	92/76
Midland/Odessa	91/70
San Antonio	90/75

III. Analysis of Event

A. Transmission Analysis

Area voltages were significantly impacted by the loss of the STATCOM, rated at +/- 150 MVAR. The trip of the STATCOM was due to a cooling system trip. A capacitor bank rated at 57.6 MVAR located at the same substation is tripped when the STATCOM trips.

Telemetry data shows area voltages momentarily dropping to 0.88 per unit at 17:17 on the 138 kV system and 1.00 per unit on the 345 kV system in the area. Following the loss of load by UVLS relays, 345 kV voltages peaked as high as 1.09 per unit and 138 kV voltages peaked as high as 1.08 per unit. Figures 9 and 10 show the trend for several 138kV and 345kV bus voltages in the area from 17:14 to 18:00 on July 3, 2015.

The loss of the STATCOM and capacitor bank was a key point in this event. Simulations conducted by Texas RE show that the loss of the STATCOM and capacitor bank created the extended low voltage condition which resulted in the UVLS relay operations in the area. The reactive power compensation of the STATCOM is a function of the voltage set point. The device is capable of providing +/- 150 MVAR. It is normally operated in voltage control mode with a typical setpoint of 1.03 per unit. The STATCOM unit tripped during this event with a cooling system trip indication. The auxiliary power to the STATCOM is critical to the operation of the cooling system. The cooling system has two pump motors that circulate coolant through the power electronics. During normal operation, one cooling pump is running and the other is on standby. If the power to the circulating pump is disturbed, the transfer switch will operate to switch to the backup feed and the backup pump. Both of the auxiliary power feeds to the transfer switch are fed from the same transmission source. If a major disturbance affects both feeds then the transfer switch does not have a good source to transfer to. This will cause the transfer to fail and the cooling system will trip off, interrupting the flow of cooling water. As a result, the STATCOM will trip off to protect the power electronics from loss of cooling. The preliminary investigation indicates that both power sources were affected by this event causing the auxiliary power transfer to fail. The capacitor bank tripped when the STATCOM tripped. The circuit breaker for the capacitor bank is interlocked with the STATCOM circuit breaker through a 52a contact in the trip logic. The loss of capacitor bank had the effect of removing an additional 57.6 MVAR of reactive support in the area and further reduced voltages in the area. The loss of the STATCOM and capacitor bank are modeled as separate, distinct contingencies in RTCA as well as the planning models; however, actual system design is set up to trip both elements which have a combined rating of 207.6 MVAR.

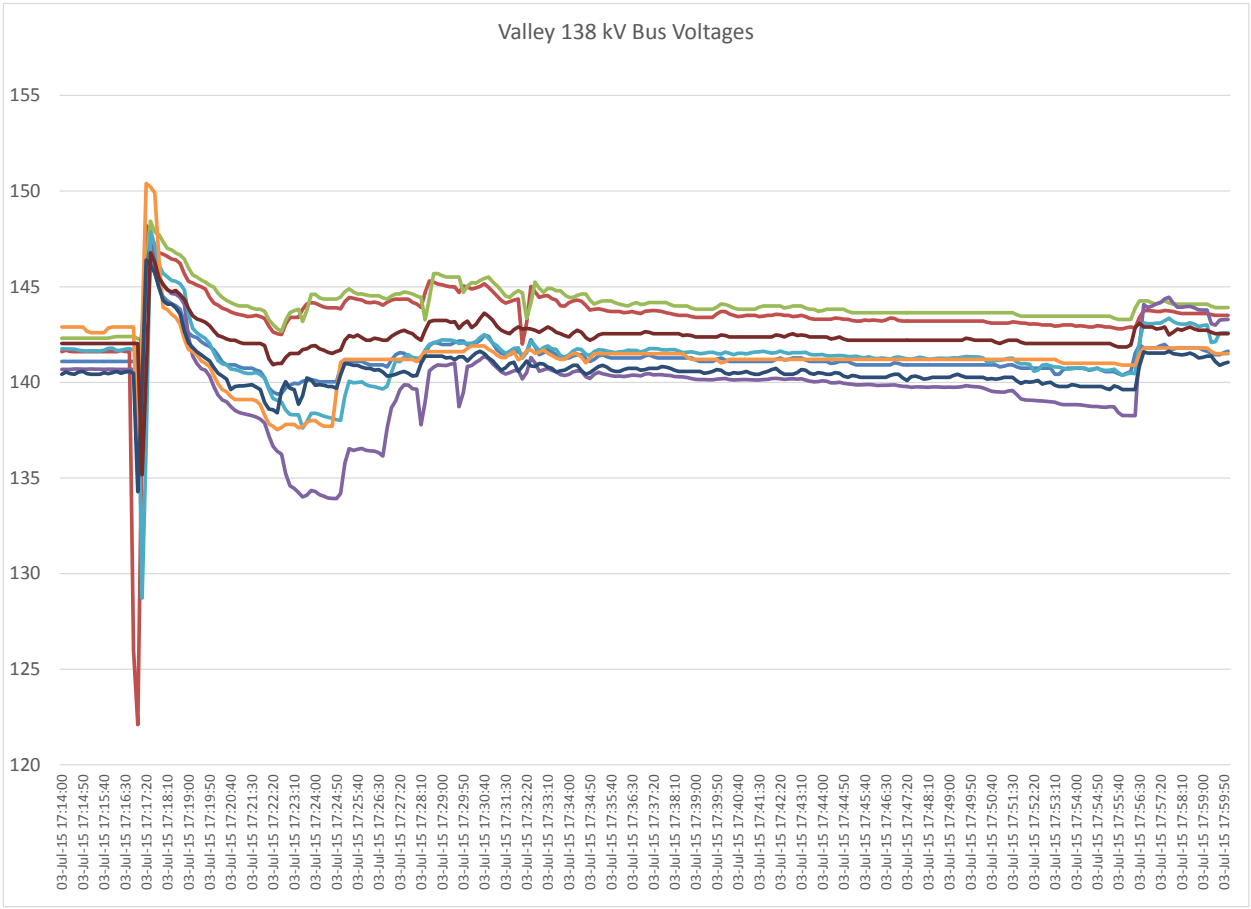

Figure 2: Rio Grande Valley 138 kV Bus Voltages July 3, 2015

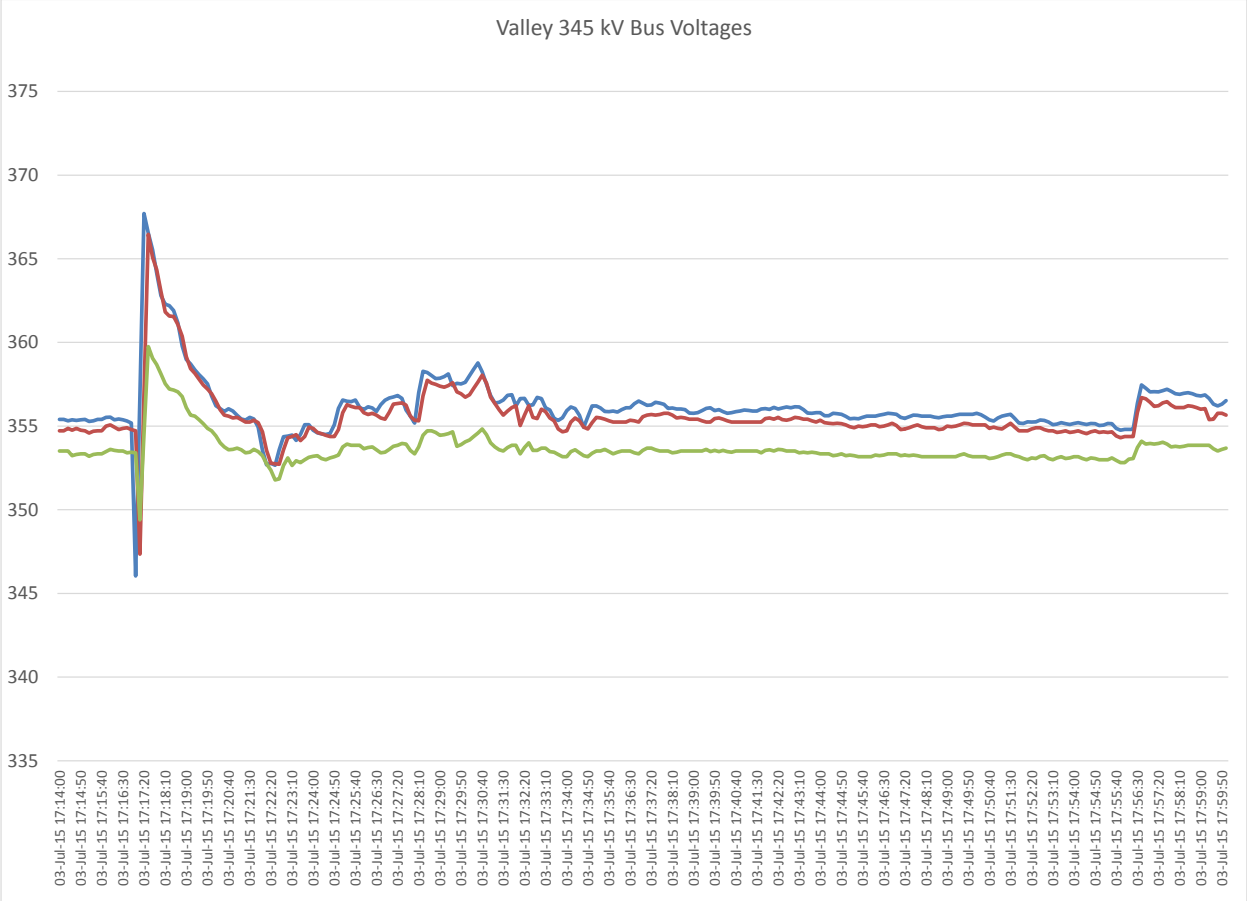

Figure 3: Rio Grande Valley 345 kV Bus Voltages July 3, 2015

End-use Customer Demand Loss

The amount of load lost during the event that was not due to the UVLS relays tripping or due to the transmission line outages was 129.5 MW. This end-use customer demand loss could be the result of motor protective device action.

Operation within System Operating Limits (SOLs)

Following the loss of the 138 kV circuit, 138 kV bus, STATCOM, and the relay misoperations, Real-Time Contingency Analysis (RTCA) showed thermal overloads on five 138 kV circuits. These post-contingency thermal violations were cleared at 17:26 when the one of the 138 kV circuit that had tripped by relay misoperation was restored.

Observations and Conclusions from Transmission Analysis

The operation of the UVLS relays occurred during the event because of the severe contingency (Category D) which included the loss of local reactive devices supporting the voltage. The loss of the STATCOM and capacitor bank was a key point in this event. If the STATCOM and capacitor bank had remained in service, the operation of the UVLS relays may not have occurred based on simulations conducted after the event.

B. Generation Analysis

The Valley area is supported by approximately 2371 MW (summer seasonal maximum MW rating) of local generation. Four generators were off-line for planned outages. Three additional generators were off-line due to market conditions. Approximately 626 MW of seasonal capacity was unavailable prior to the event.

Impact of Wind Generation

A total of four wind plants at two sites are connected to the 138 kV transmission system in the area. Seven additional wind plants are connected to the 345 kV transmission system north of the area. These wind plants have a nameplate capacity of 1495 MW. The following graph shows the Valley generation during the event. The changes in the total Valley generation were due to changes in the wind generation output.

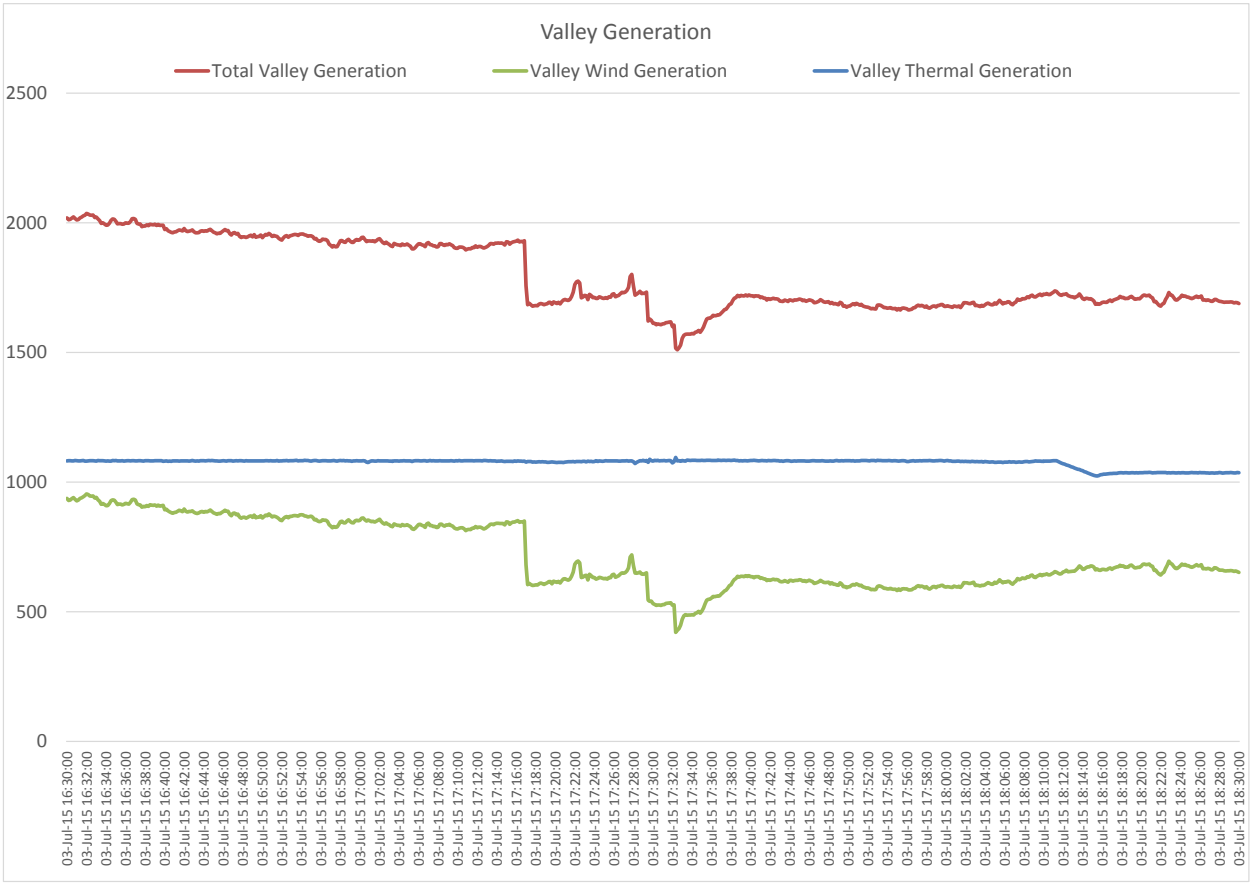

Figure 4: Valley Generation

Multiple wind facilities exhibited a loss of MW output during the event. Approximately 475 MW of wind generation tripped at various times during the event. The loss of MW output appeared to be related to the voltage disturbance(s) that occurred on the system due to the initial fault and subsequent faults that occurred during attempts to re-energize the failed 138 kV circuit.

Plant	# Turbines Tripped	Comment
Wind Plant #1	87	87 of 87 turbines tripped, 9 at 17:17, 22 at 17:21, and the rest at 17:29. Reported voltage fluctuations from 133 to 148.3 kV.
Wind Plant #2	12	12 of 70 turbines tripped on initial disturbance. Reported voltage fluctuations from 141.4 to 148.6 kV.
Wind Plant #3	74	74 of 108 turbines tripped due to repeated voltage fluctuations at 17:32.
Wind Plant #4	42	42 of 115 turbines tripped on initial disturbance. Reported sustained voltages from 0.60 to 0.89 per unit at the POI.
Wind Plant #5	64	54 of 145 turbines tripped on initial disturbance due to "grid voltage failure" alarms. Reported voltage fluctuation from 340.5 to 367.2 kV.
Wind Plant #6	0	No observed impact

Wind Plant #3 reported that loss of 74 of 108 turbines at 17:32. The turbines are equipped with voltage ride-through (VRT) capability, but will trip if there is not enough recovery time between voltage excursions to prevent damage to the turbine.

Wind Plant #3 Sequence of Events

17:16:42 – Initial grid event (1st voltage deviation) – 112 turbines on-line
17:16:43 – 2nd voltage deviation – no turbines tripped due to voltage deviation
17:16:44 – 3rd voltage deviation – no turbines tripped due to voltage deviation
17:22:25 – 4th voltage deviation – no turbines tripped due to voltage deviation
17:23:05 – 5th voltage deviation – no turbines tripped due to voltage deviation
17:23:25 – 6th voltage deviation – no turbines tripped due to voltage deviation
17:27:49 – 7th voltage deviation – no turbines tripped due to voltage deviation
17:29:19 – 8th voltage deviation – no turbines tripped due to voltage deviation
17:29:44 – 9th voltage deviation – no turbines tripped due to voltage deviation
17:31:50 – 10th voltage deviation – 108 turbines on-line
17:32:08 – 11th voltage deviation – 74 turbines trip as designed to prevent damage

Generator Automatic Voltage Support

All on-line fossil-fueled units in the Valley were operating with the Automatic Voltage Regulator (AVR) in "AUTO" and in Voltage Control mode at the time of the event. The AVRs responded as expected in the appropriate direction when voltage peaked and sagged to provide the necessary amount of lagging or leading Reactive capability to support voltage.

Observations and Conclusions from Generation Analysis

Fossil units in the Valley provided appropriate reactive support to maintain system voltages during the event. The loss of wind generation real and reactive power capability was a contributing factor and needs further review.

C. Under-Voltage Load Shed Activation

Local transmission providers in the Valley area have automatic undervoltage load shed (UVLS) schemes (with slight variations) in service to shed load to prevent uncontrolled loss of load and outages. The UVLS scheme has two setting levels; one level has a one-time delay setting that trips approximately 30% of the load in two seconds at 75% or 85% voltage level depending on load location in the Valley. The second level has multiple time delay settings that trip load at 90% voltage. A total of 92.04 MW of load and 23,921 customers were impacted by UVLS feeders that tripped during the event.

Data from the UVLS feeder relays indicates the 12 kV voltage was below 85% for approximately 2.05 seconds and below 90% for up to 3.3 seconds.

One UVLS relay failed to operate properly for this event due to a blown fuse on the voltage input to the relay.

During the event, transmission and distribution system operators restored their feeders that tripped by UVLS relay without prior approval from ERCOT. At two substations, there was no indication in SCADA that they tripped by UVLS. The relay would normally send an alarm to the host SCADA that the breaker tripped by UFLS/UVLS. While it was field verified that two substations shed load by the UVLS relay, the SCADA host never alarmed, thus the distribution operators were not aware that the load was tripped by the UVLS relay and therefore acted to restore service per standard practice. It was verified that the alarm is on the RTU point list to the host but it has not determined why it did not alarm correctly at the host.

D. Protection System Performance

The following protection system performance issues were noted during this event:

Issue	Cause
Protection system overtripped due to failure to receive carrier blocking signal from the remote terminal	Relay was found locked up due to a memory error
Protection system overtripped due to failure to receive carrier blocking signal from the remote terminal	Power line carrier was found without DC power due to a frog getting inside the carrier set and shorting out the DC circuit
UVLS relay failed to trip	Found a blown fuse on the voltage input to the relay

Table 2: Valley Area Protection System Performance Issues