# Solar Generation Loss Event
# January 23, 2023

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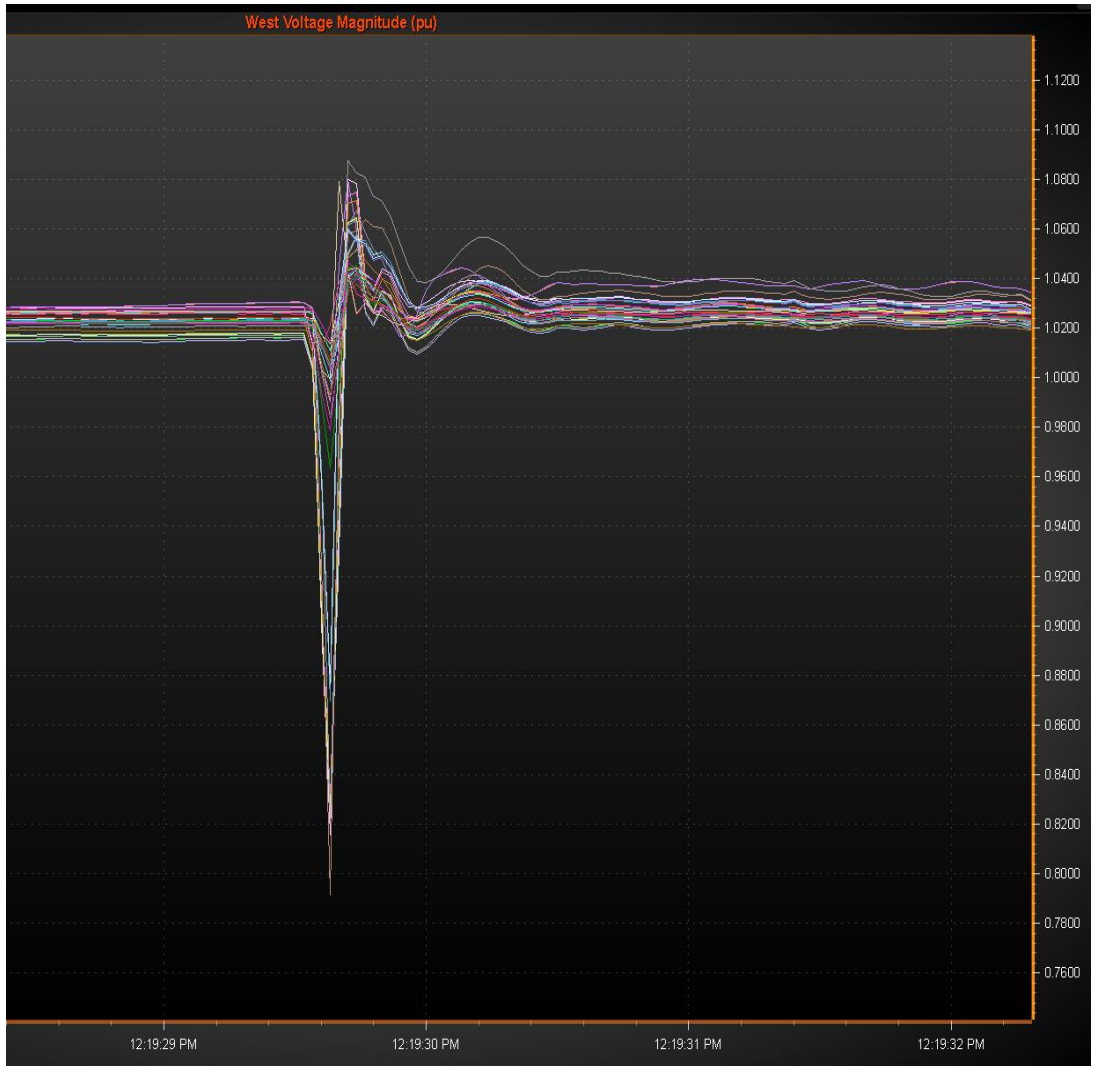
# January 23 Event Overview

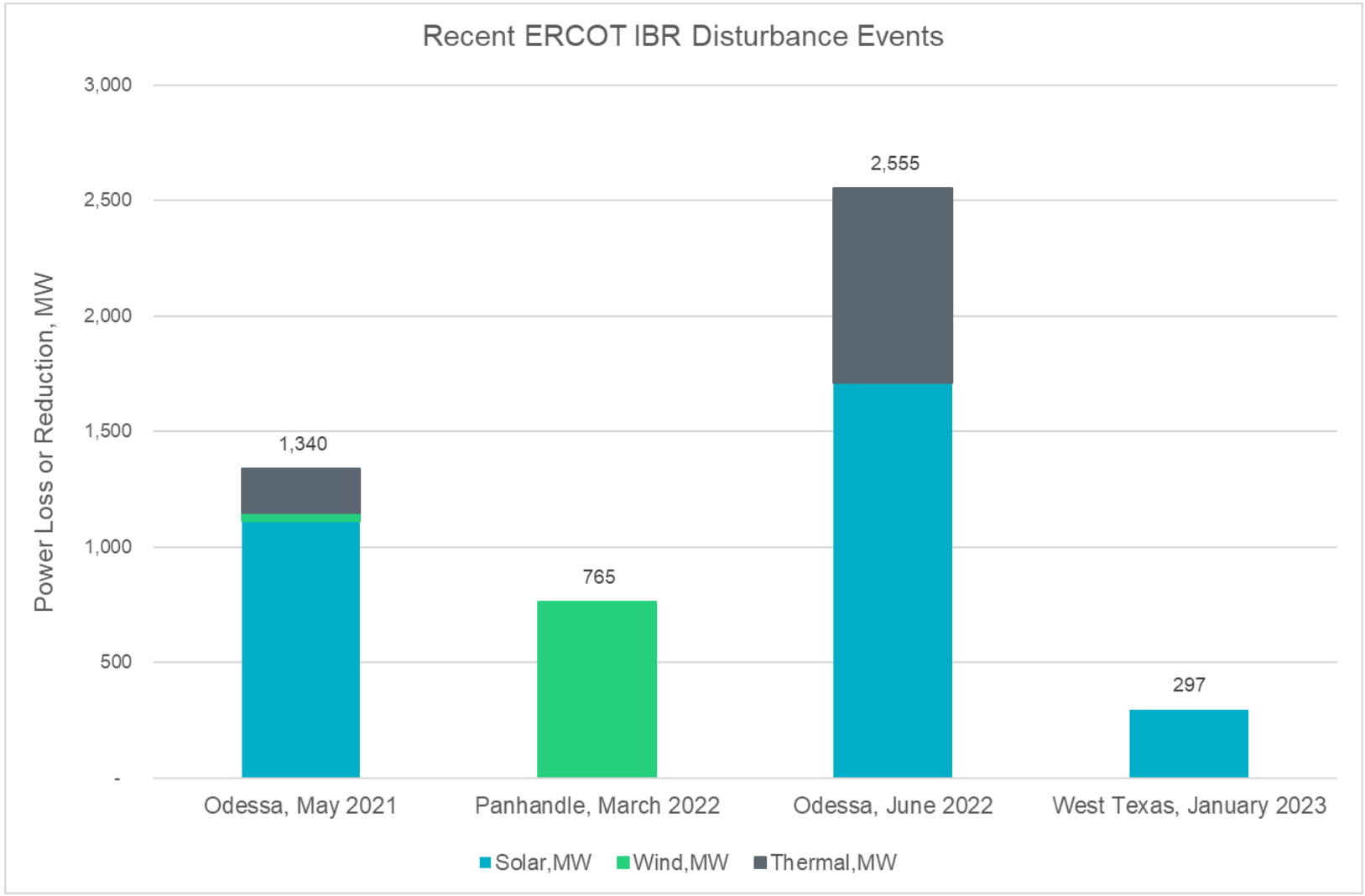
- On January 23, 2023, @ 12:19 PM CST, Phase-A-to-ground fault occurred on 138 kV line in West Texas
- Fault cleared normally in 3 cycles
- Analysis shows approximate non-consequential loss of 297 MW of solar generation from 8 different facilities
- Aggregate MW loss includes facilities that did not return to pre-disturbance output within 1 second after the fault cleared
- 7 of 8 facilities involved in Odessa events
- ~208 MW of load reduction occurred at four different LFL sites (crypto) immediately following fault
- System frequency dropped to 59.955 Hz and recovered in 6 seconds
- PMU/ relay event data requested from 25 surrounding solar facilities; 20 submitted PMU data
- No significant Wind/BESS reductions seen in SCADA (>10MW)
- RFIs sent to 8 facilities with due date of Feb. 24 – several needed follow up questions or have pending investigations
- Several facilities involved in Odessa events did not see voltage excursions large enough to test mitigation actions; others initially show an improvement in performance (less inverter tripping)

# PMU Voltage During Event




- Lowest voltage of 0.677 pu recorded at 138 kV station close to fault
- Highest voltage of 1.088 pu recorded at 69 KV station in Far West Texas
- Lowest recorded voltage on 345 kV system was 0.878 pu; highest was 1.07 pu
- Voltage remained within NOG VRT “No Trip Zone”
- Phase angle jumps in West Texas in the 10-to-15-degree range (over ~100 ms – 200 ms time frame)

# ERCOT IBR Disturbance Events



# Solar Capacity and Output During Recent Events

| Event | Odessa 2021 | Odessa 2022 | West Texas 2023 |
|---|---|---|---|
| Date/Time | May 9, 2021 @ 11:21 CT | June 4, 2022 @ 12:59 CT | January 23, 2023 @ 12:19 CT |
| Installed Solar Capacity | 7,505 MW | 11,440 MW | 14,249 MW |
| Solar Output at Time of Event | 4,533 MW | 8,740 MW | 8,236 MW |
| Solar % of Total Generation at Time of Event | 9% | 15.8% | 17.9% |

# Facilities with MW Loss After Fault Clearing

| Facility ID* | OEM | Low Voltage During Fault | Pre-Disturbance Output | MW Reduction During Fault | MW Loss Post Fault | Recovery Time | Root Cause |
|---|---|---|---|---|---|---|---|
| Plant A** | KACO | 0.728 pu (138) | 141 MW | 27 MW | 6 MW | 6 minutes | Inverters went into idle mode. Cause unknown. |
| Plant B | TMEIC | 0.721 pu (138) | 145 MW | 118 MW | 111 MW | 7 seconds | Inverter ramp rate set to 10%/second. |
| Plant F | KACO | 0.862 pu (69) | 40 MW | 20 MW | 17 MW | 6 minutes | Inverters tripped due to AC overcurrent protection. |
| Plant K/L | PE | 0.877 pu (138) | 91 MW | 91 MW | 74 MW | 6 minutes | Most inverters entered momentary cessation with a small number tripping on overcurrent. Unknown slow ramp rate post disturbance; potential PPC interaction due to frequency. |
| Plant M | PE | 0.793 pu (138) | 67 MW | 32 MW | 32 MW | 2 seconds | Large MW swings post disturbance. Improper LVRT setting. |
| Plant N/O | KACO | 0.793 pu (138) | 120 MW | 47 MW | 30 MW | 10 seconds | Unknown cause of delayed recovery; Still investigating. One inverter trip current imbalance. |
| Plant P | KACO | 0.642 pu (138) | 132 MW | 37 MW | 1.5 MW | 4 minutes | One inverter tripped to AC overcurrent. |
| Plant W*** | PE | 0.858 pu (345) | 229 MW | 229 MW | 25 MW | 1 minute | Unknown cause of slow ramp rate post disturbance. |
| **Totals** | | | | **601 MW** | **297 MW** | | |

*Facility ID corresponds with NERC 2022 Odessa Disturbance Report Table A.1
**Facility involved in 2021 Odessa Event but not 2022 Odessa Event
***Facility not involved in either 2021 or 2022 Odessa Events

# Causes of Solar PV Active Power Reductions

| Cause of Reduction | Odessa 2021 Reduction (MW) | Odessa 2022 Reduction (MW) | West Texas 2023 Reduction (MW) |
|---|---|---|---|
| Inverter Instantaneous AC Overcurrent | - | 459 | 18.5 |
| Passive Anti-Islanding (Phase Jump) | - | 385 | - |
| Inverter Instantaneous AC Overvoltage | 269 | 295 | - |
| Inverter DC Bus Voltage Unbalance | - | 211 | - |
| Feeder Underfrequency | 21 | 148* | - |
| Unknown/Misc. | 85 | 96 | 61 |
| Incorrect Ride-Through Configuration | - | 135 | 147 |
| Plant Controller Interactions | - | 146 | 74 |
| Momentary Cessation | 153 | 130 | 74** |
| PLL Loss of Synchronism | 389 | - | - |
| Feeder AC Overvoltage | 147 | - | - |
| Inverter Underfrequency | 48 | - | - |

*In addition to inverter-level tripping
**Facility had momentary cessation and plant controller interactions

# Facilities with MW Loss (Jan. 23 and Odessa Event Comparison)

| Facility ID | OEM | MW Loss Odessa | Odessa Root Cause | Corrective Actions | MW Loss Jan. 23 | Jan. 23 Root Cause | Corrective Actions |
|---|---|---|---|---|---|---|---|
| Plant A* | KACO | 28 MW | Unknown | None | 6 MW | Inverters went into idle mode. Cause unknown. | Still investigating; need to improve inverter logging capabilities. |
| Plant B** | TMEIC | 133 MW | PLL Loss of Synch Volt Phase Jump | Disabled functions | 111 MW | Inverter ramp rate set to 10%/second. | Change inverter ramp rate to 100%/sec. |
| Plant F | KACO | 46 MW | Unknown | Increase VRT/FRT settings; improve inverter logging capabilities | 17 MW | Inverters tripped due to AC overcurrent protection. | Still investigating; Undetermined if overcurrent issue can be improved in KACO inverters. |
| Plant K/L | PE | 130 MW | Momentary cessation/ Power supply failure | Enable LVRT/MC to speed recovery | 74 MW | Unknown slow ramp rate post disturbance; potential PPC interaction due to frequency event. | Adjusting inverter ramp rate; investigating potential PPC interaction. |
| Plant M | PE | 146 MW | Incorrect inverter ride through configuration | Enable LVRT and tuned settings to improve ride through performance | 32 MW | Large MW swings post disturbance. Improper LVRT setting. | Change LVRT threshold from 0.5pu to 0.9pu. PSCAD model to determine cause of oscillations; improved response. |
| Plant N/O | KACO | 50 MW | Unknown | Increase VRT/FRT settings; improve inverter logging | 30 MW | Unknown cause of delayed recovery; Still investigating. One inverter trip current imbalance. | Undetermined; improved response from Odessa events since minimal inverter tripping. |
| Plant P | KACO | 10 MW | Inverter tripping to AC overcurrent | None | 1.5 MW | One inverter tripped to AC overcurrent. | Undetermined if overcurrent issue can be improved in KACO inverters. |
| Plant W | PE | N/A | N/A | N/A | 25 MW | Unknown cause of slow ramp rate post disturbance. | Still investigating. |

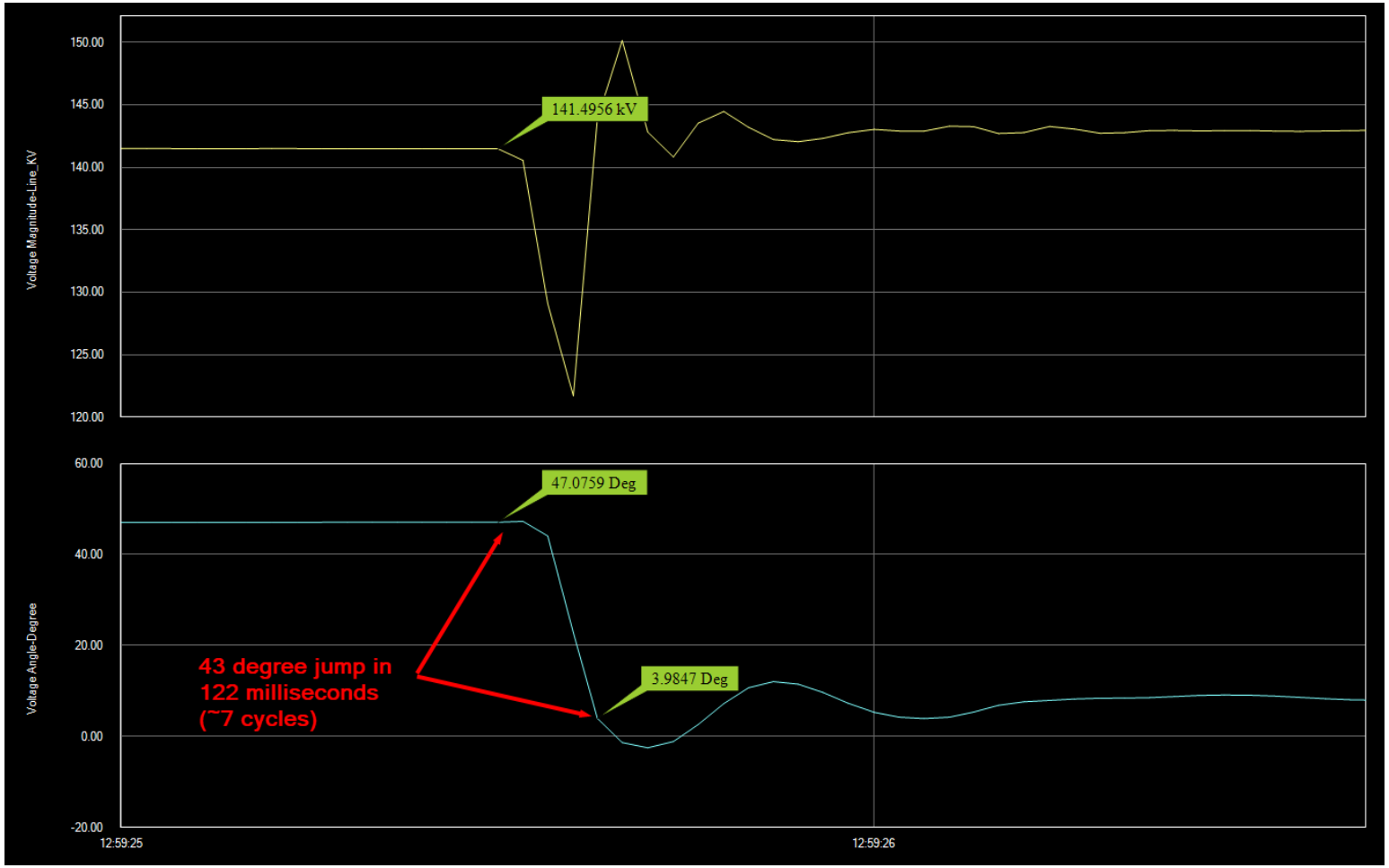
*Data used from 2021 Odessa event
** PLL Loss of Synch for 2021 Odessa and Volt Phase Jump for 2022 Odessa

# TMEIC Facilities (Jan. 23 and Odessa Event Comparison)

| Facility ID | MW Loss During Odessa | Odessa Root Cause | Corrective Actions | MW Reduction Jan. 23* (During Fault) | Odessa Low/High Voltage** | Jan. 23 Low/High Voltage | Odessa Phase Jump*** | Jan. 23 Phase Jump |
|---|---|---|---|---|---|---|---|---|
| Plant C | 56 MW | Volt Phase Jump | Increase VPJ threshold to 35°; increase OVRT settings; reduce k-factor | 3 MW | 0.8120 pu (345)<br>1.0661 pu**** | 0.878 pu<br>1.0675 pu | 32.2° | 12.5° |
| Plant E/U | 295 MW | Inverter AC overvoltage tripping | Increase VPJ threshold to 35°; increase OVRT settings; reduce k-factor | 2 MW | 0.9014 pu (138)<br>1.0543 pu | 1.0014 pu<br>1.0518 pu | 28° | 7.7° |
| Plant I/J | 196 MW | Volt Phase Jump | Increase VPJ threshold to 35°; increase OVRT settings; reduce k-factor | 0 MW | 0.7814 pu (345)<br>1.0116 pu | 0.9623 pu<br>1.0566 pu | 32.2° | 10.8 |
| Plant R | 261 MW | Inverter AC overcurrent tripping | Increase VPJ threshold to 35°; increase OVRT settings; reduce k-factor | 0 MW | 0.8819 pu (138)<br>1.0881 pu | 0.9605 pu<br>1.0830 pu | 43.1° | 13.1° |
| Plant T | 176 MW | Inverter AC overcurrent tripping | Increase VPJ threshold to 35°; increase OVRT settings; reduce k-factor | 1 MW | 0.8818 pu (138)<br>1.0881 pu | 0.9641 pu<br>1.0674 pu | 42° | 7.5° |

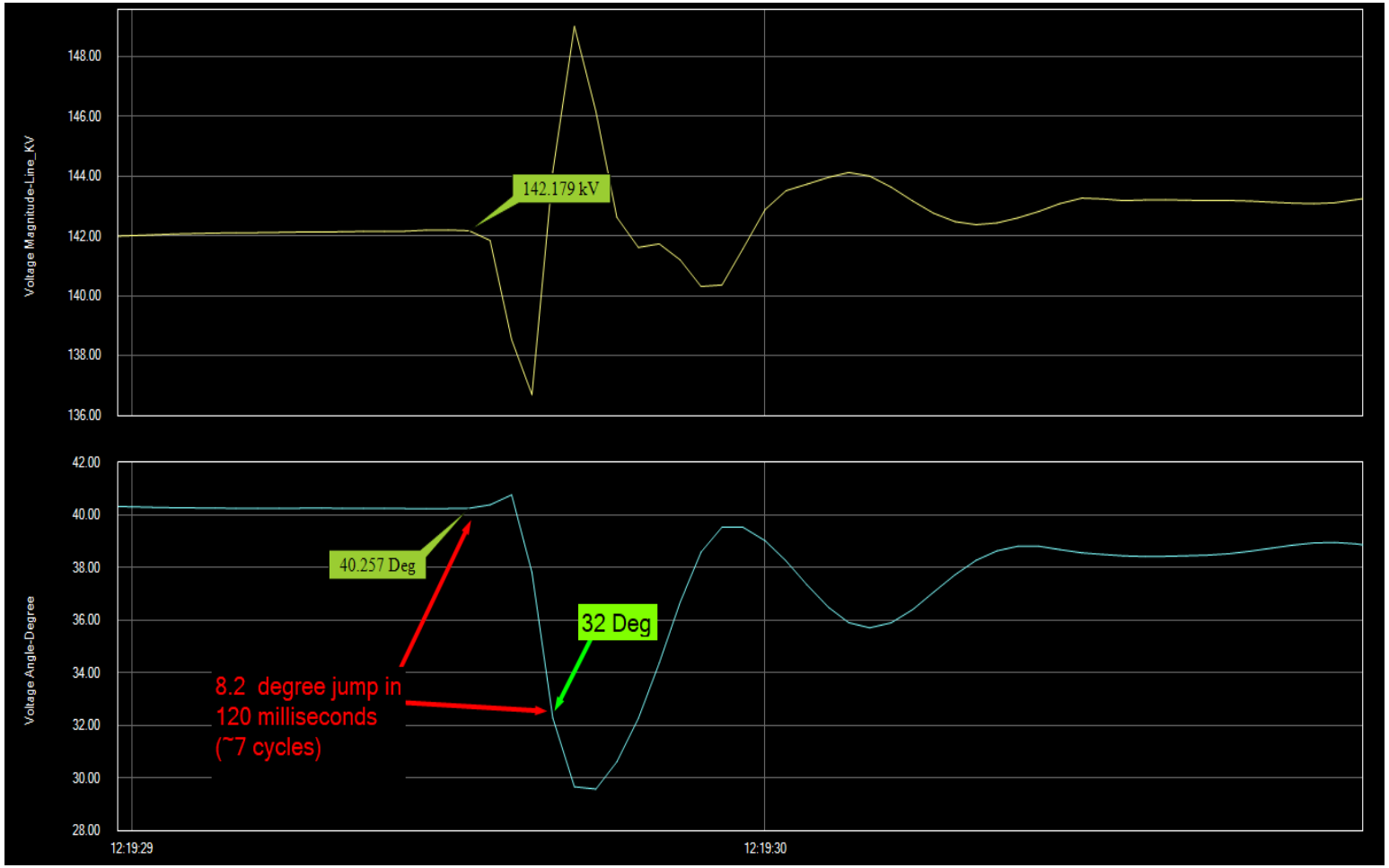
*All facilities in table above returned to pre-disturbance output within 0.5 seconds of fault clearing
**Voltage magnitude from PMU data either at facility or POI
***Phase angle jump is positive sequence change in PMU phase angle data during fault (~100-200 ms)
****No PMU data at site. Data from nearby 345 kV station

# Phase Angle Jump – PMU Data - Odessa




- PMU positive sequence voltage angle in Far West Texas referenced to voltage angle in Central Texas
- Angle jump of ~43° in 122 ms (~7cycles)
- IEEE 2800 refers to phase angle changes within sub-cycle-to-cycle time frame of <= 25°
- Further work needed to determine sub-cycle-to-cycle phase angle change for these events (PMU data not sufficient)

# Phase Angle Jump – PMU Data – Jan. 23 Event




- Phase Angle jump of ~8.2° in 120 ms (~7 cycles)

# Additional Units that Rode Through* Jan. 23 Event

| Facility ID | OEM | Low Voltage During Fault | Pre-Disturbance Output | MW Reduction During Fault | Notes |
|---|---|---|---|---|---|
| Plant Q | PE | 0.917 pu (138) | 123 MW | 45 MW | Lost 12 MW in 2022 Odessa due to inverter overcurrent tripping. No inverters tripped on 1/23 but reduced significant MWs during fault for voltage remaining above 0.9pu. |
| Plant S | PE | 0.975 pu (138) | 81 MW | 81 MW | Lost 94 MW in 2022 Odessa due to all inverters tripping on Vdc bus unbalance. No inverters tripped on 1/23 but active power reduced to 0 MW during fault. |
| Plant V | PE | 0.980 pu (345) | 113 MW | 29 MW | Lost 106 MW in 2022 Odessa due to all inverters tripping on Vdc bus unbalance. No inverters tripped on 1/23. |
| Plant AA | GE | 0.874 pu (345) | 84 MW | 84 MW | Active power drops to 0 MW during fault. |
| Plant BB | Sungrow | 0.675 pu (138) | 55 MW | 15 MW | Optimal active power ride though. |
| Plant CC | GE | 0.962 pu (345) | 204 MW | 12 MW | Dropped to 0 MW during Odessa 2022 event (0.831 pu voltage); worked with OEM to improve inverter performance and reduce active power drop. |
| Plant DD | SMA/GE | 0.870 pu (138) | 18 MW | 18 MW | Active power drops to 0 MW during fault. |
| Plant EE | PE | 0.956 pu (138) | 39 MW | 6 MW | |
| Plant FF | Sungrow | 0.954 pu (138) | 125 MW | 4 MW | |
| Plant GG | PE | 0.937 pu (138) | 100 MW | 22 MW | |
| Plant HH | Sungrow | 0.912 pu (345) | 341 MW | 26 MW | |
| Plant II | Schneider | 0.880 pu (345) | 115 MW | 51 MW | |
| **Total** | | | | **393 MW** | |

*All recovered to pre-disturbance output in < 1 second after fault clearing

# Summary and Misc.

- Far less inverter tripping during Jan. 23 event compared to Odessa events
- Majority of inverter tripping due to overcurrent; most difficult to mitigate due to potential inverter damage and logic changes required by OEM
- Most MW loss post fault likely due to PPC/inverter interactions causing delayed recovery– investigations still ongoing
- Difficult to determine effectiveness of corrective actions implemented since Odessa events
- Additional discussion and corrective actions needed to minimize active power reduction during faults; REs need to be proactive in this analysis to improve response
- Wide range of reactive responses from facilities during fault; potential future IBRTF discussions needed
- ERCOT is using this event to validate submitted dynamic models; REs will be contacted when simulated performance does not match actual performance

# Questions?