System Operation Post-Commissioning

Reliability Improvement

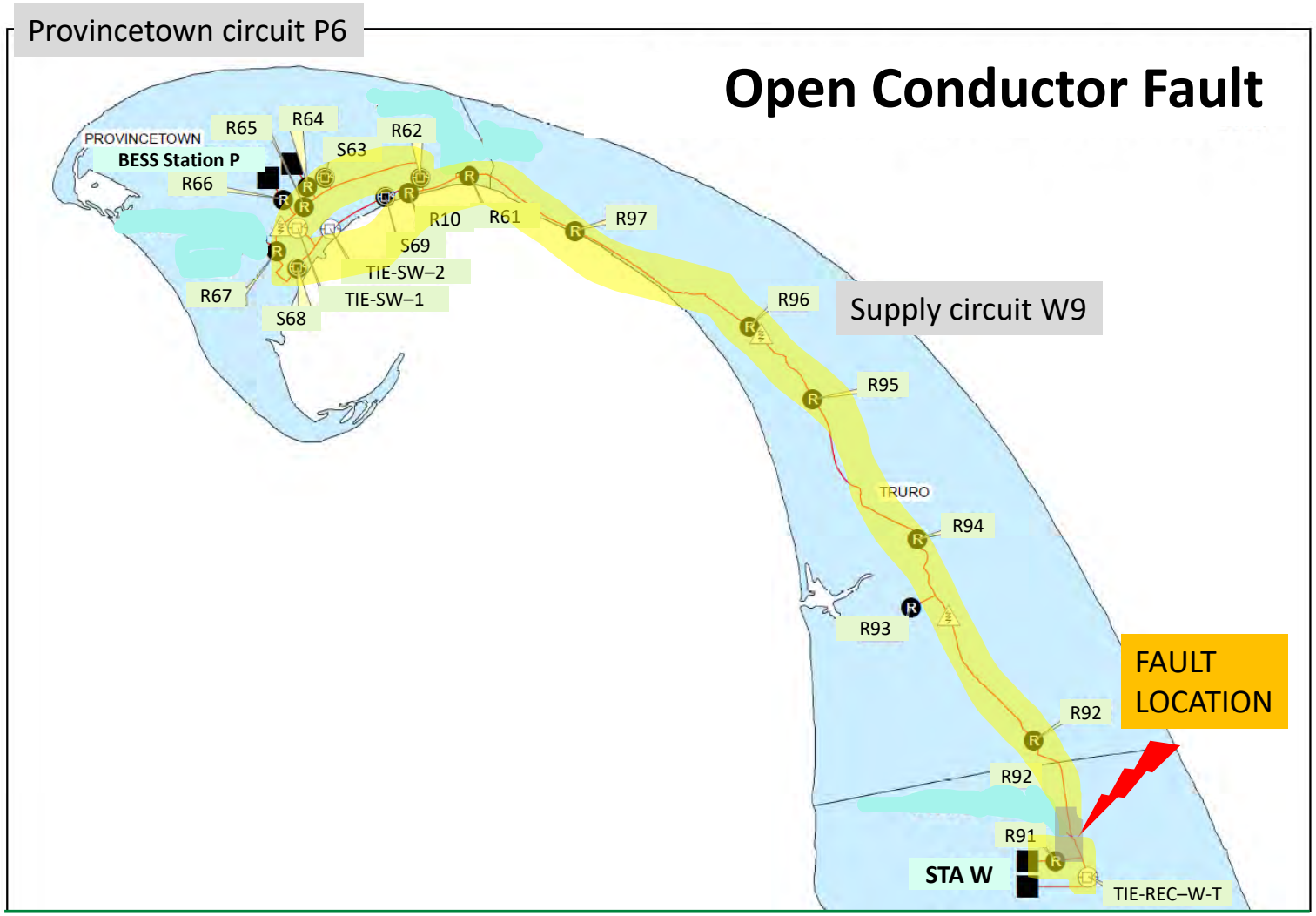
Outage Mitigation and Reliability Improvement

- May 4, 2023 – Open conductor fault occurs near source substation. BESS carries all load until fault is isolated and repairs are completed (outage avoided for 9,917 customers for 42 min.).

- Dec. 18, 2023 - Major storm impacts region. BESS and Microgrid performance following three faults avoids outages for 11,966 customers.

  1. Circuit W9 event at 8:36:44 AM – Provincetown load island established with BESS
  2. Circuit P6 event at 12:53:48 pm – While system connected and BESS recharging at 87%
  3. Circuit W9 event at 1:42:04 PM – Provincetown load island established with BESS

- A projected benefit of this BESS and microgrid system was an 80% reduction in customer-minutes interrupted (CMI) for similar events if we still had the previous circuit and device configuration (no BESS or microgrid).
- The actual benefit from these 3 islanding events was a *91% reduction in CMI*.



May 4, 2023

Fault – open phase conductor near source station W. Only 133 customers interrupted in fault area for 42 minutes while repairs were made.

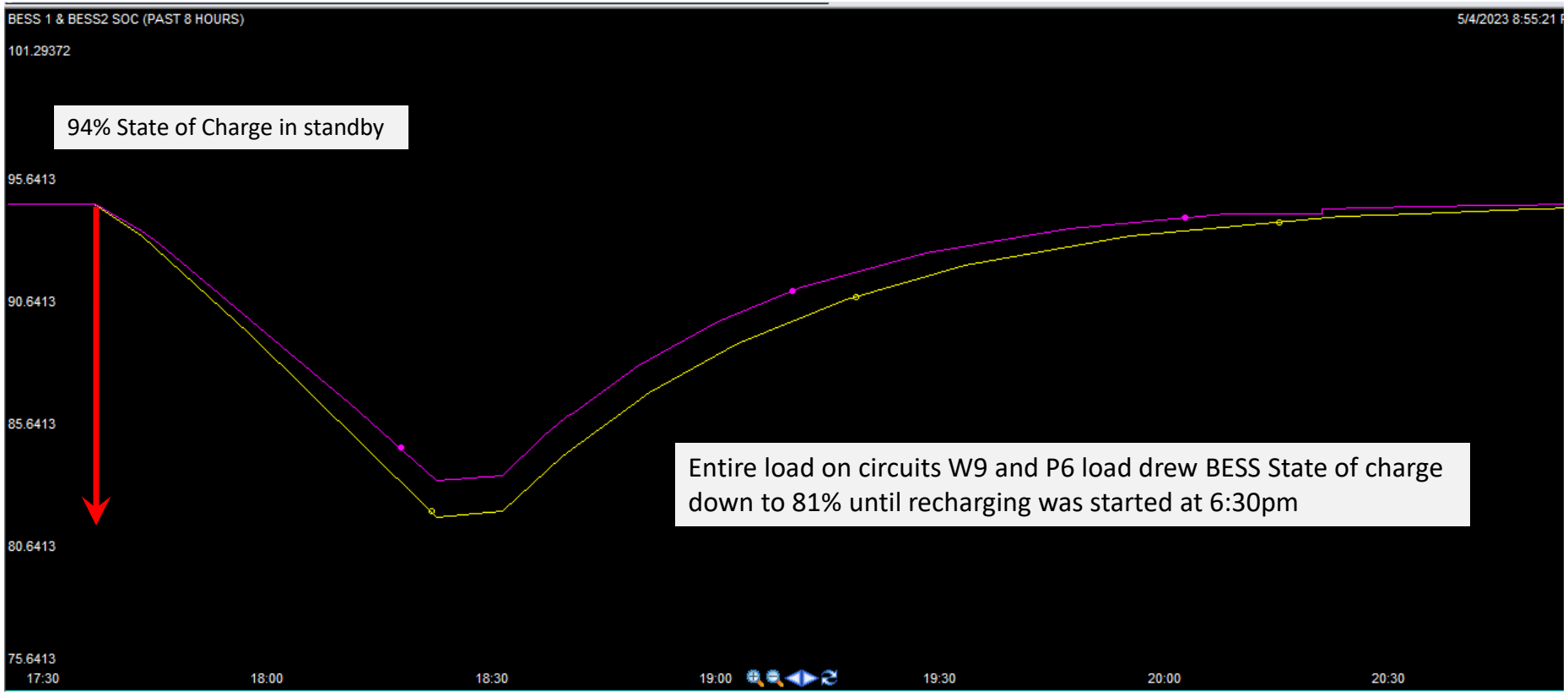
Cause: Connector and single phase tap wire burnt open just beyond Station W

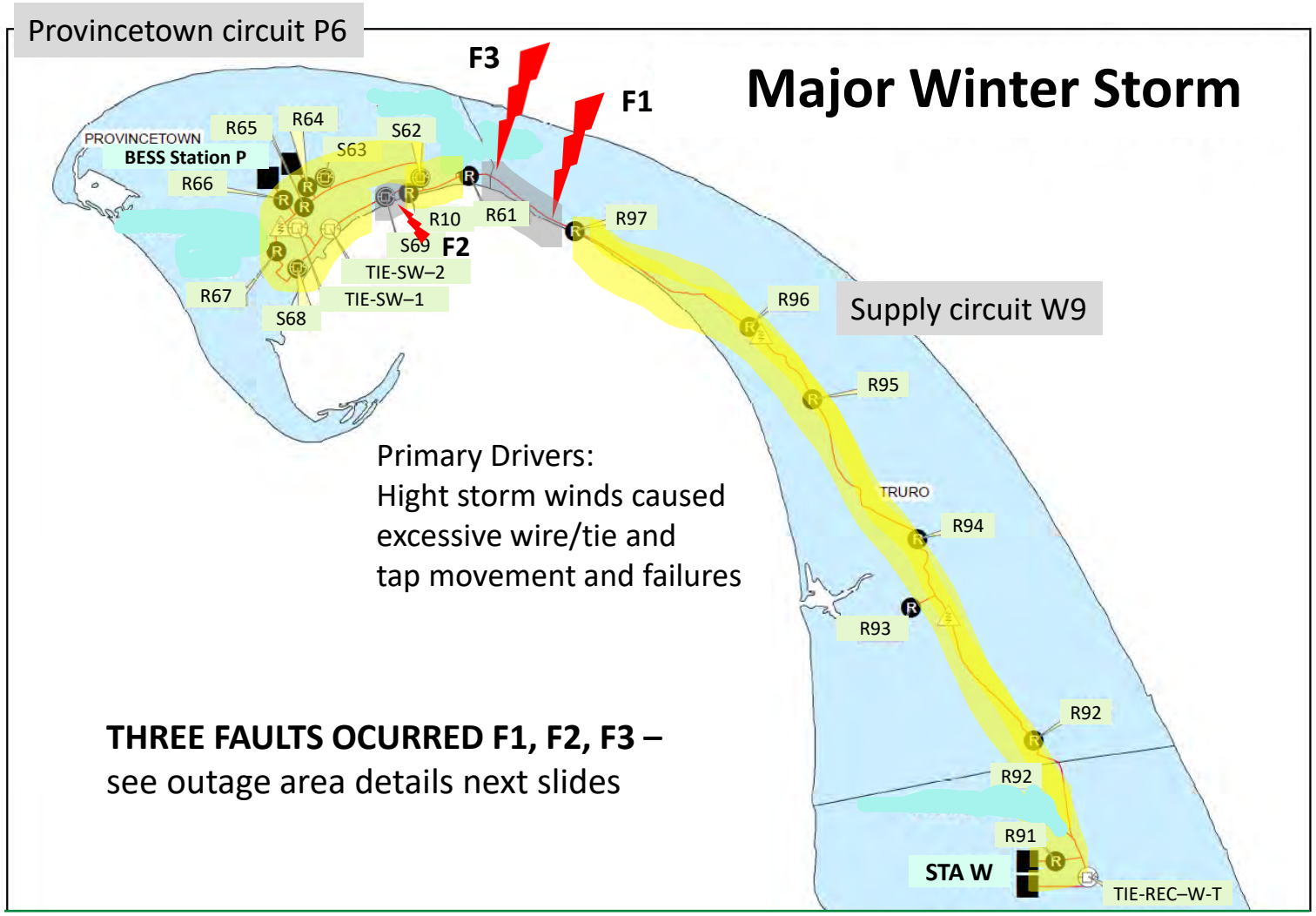
BESS Engaged automatically and carried all load for 42 minutes. No microgrid device operations needed.

Outage avoided for 9,917 customers across three towns.

BESS discharged from 94% to 81%

BESS Charge Levels Around Islanding Event on May 4, 2023





Dec 18, 2023

Fault #1 impacted 611 customers for 2 hours and 20 mins. (328 in Truro and 283 in Provincetown)

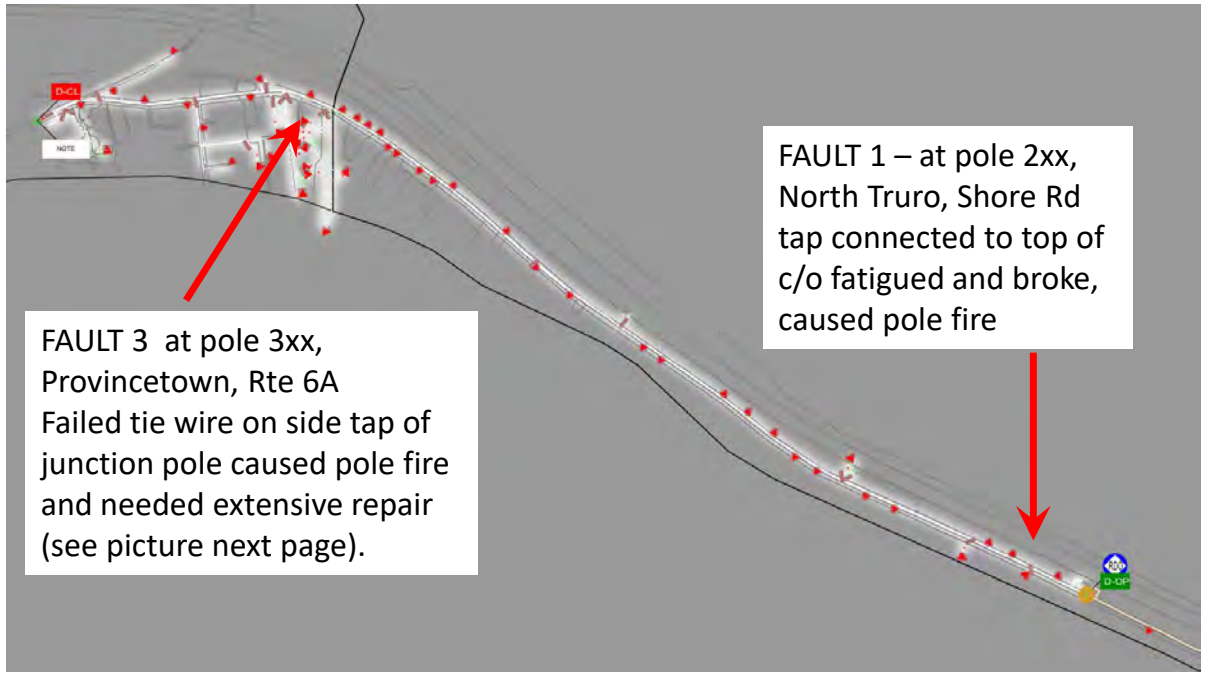
Cause: Wind and pole/wire movement caused broken tap and pole fire at 3 ph tap pole.

Recloser R97 tripped to isolate fault beyond it (dark area F1), Point of Common Coupling (PCC) R61 recloser opened on Direct Transfer Trip (DTT) to form island in Provincetown. Outage averted for 5,662 customers

BESS discharged from 95% to 73%

Fault #1 and #3 were in the same circuit zone, affected same customers

Provincetown -Truro border



Fault #3 impacted 611 customers for 6 hours and 49 mins. (328 in Truro and 283 in Provincetown)

Cause: Wind and pole/wire movement caused wire tie to fail and pole fire extensive damage

Recloser R97 tripped to isolate fault, PCC R61 opened on DTT to form island. Outage averted for 5,662 customers

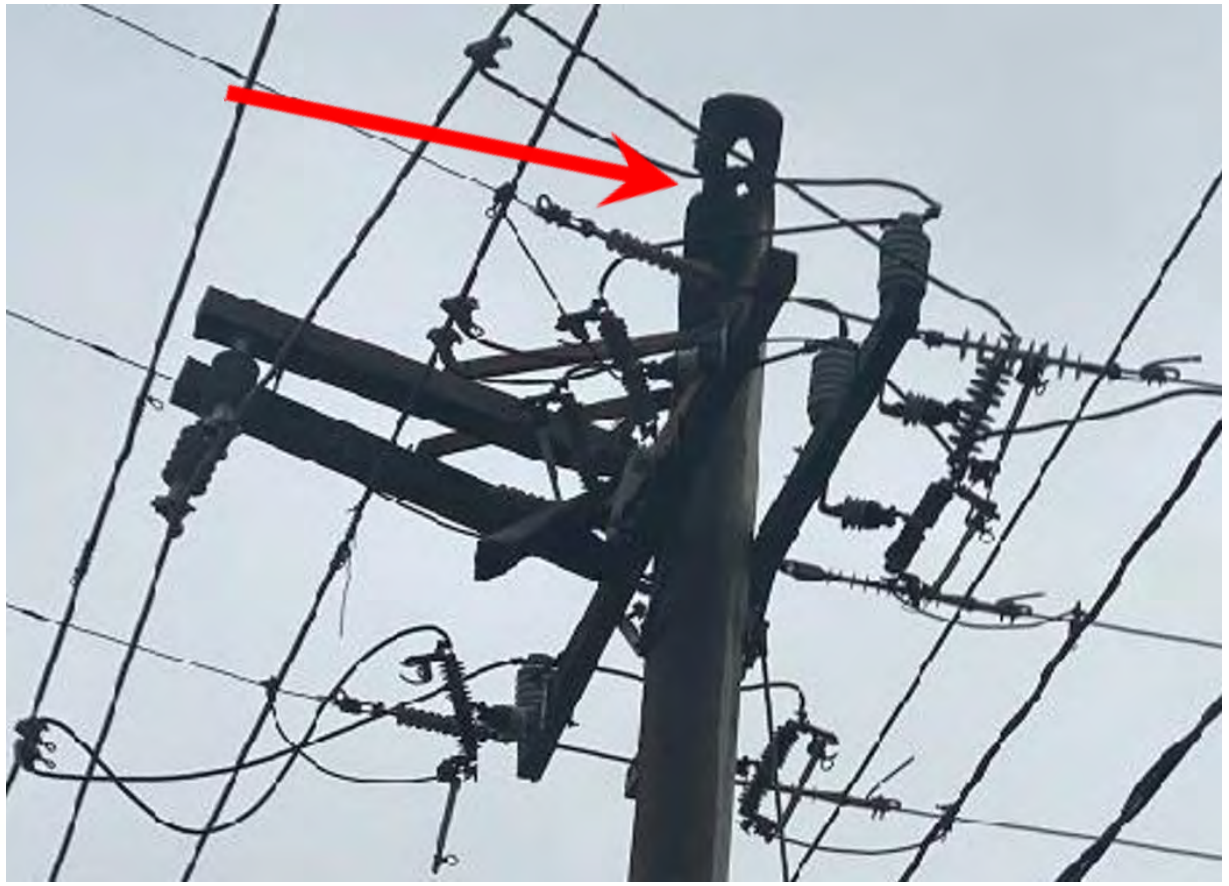
BESS discharged from 95% to 28% Delays in synchronizing did not extend outage beyond 6 hr, 49 min repair time needed, but BESS SoC continued to drop.

Fault #3 caused extensive damage

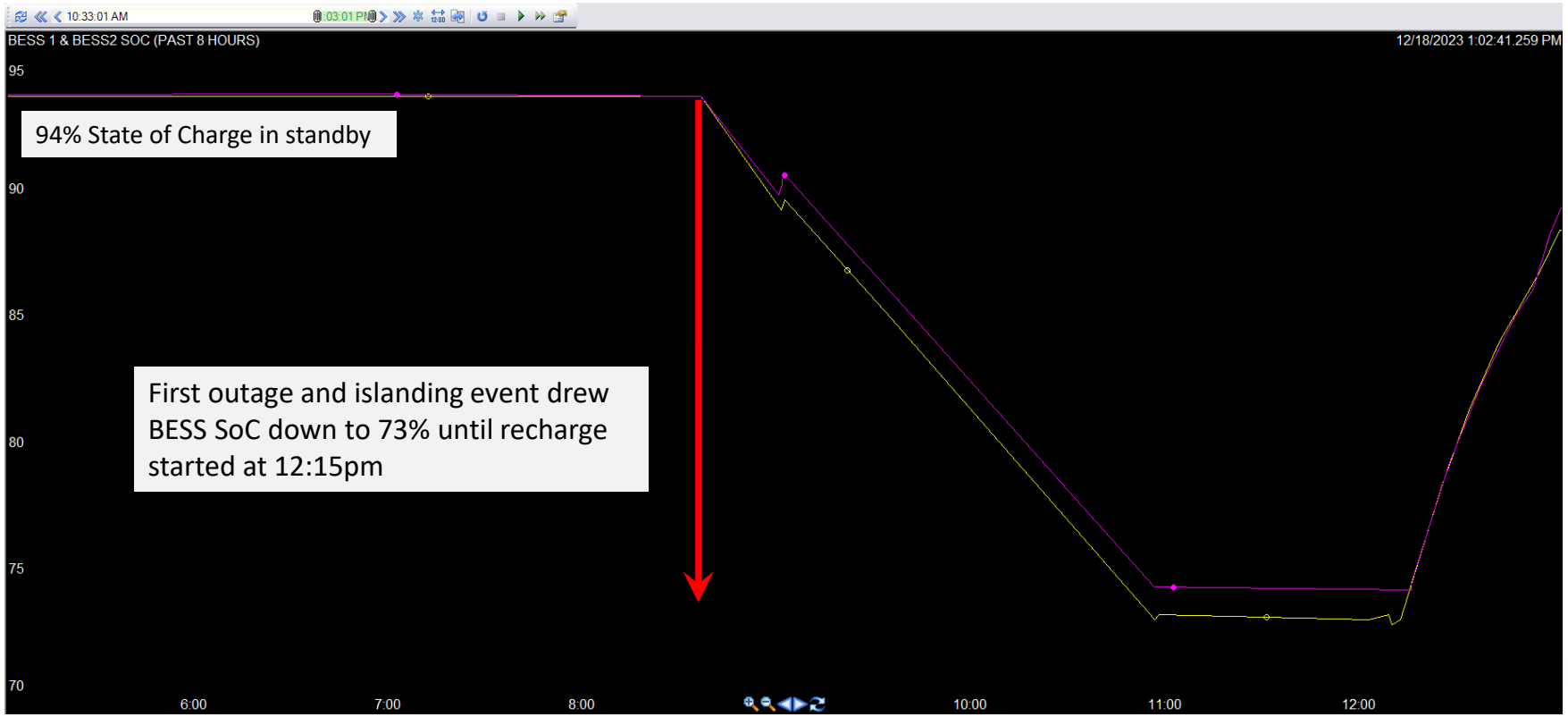
Near Provincetown – Truro Border

A failed tie wire on a side tap of 4-way junction caused loose tap and ground contact through pole.
Appears that tap shorted to brace hardware and started pole fire.

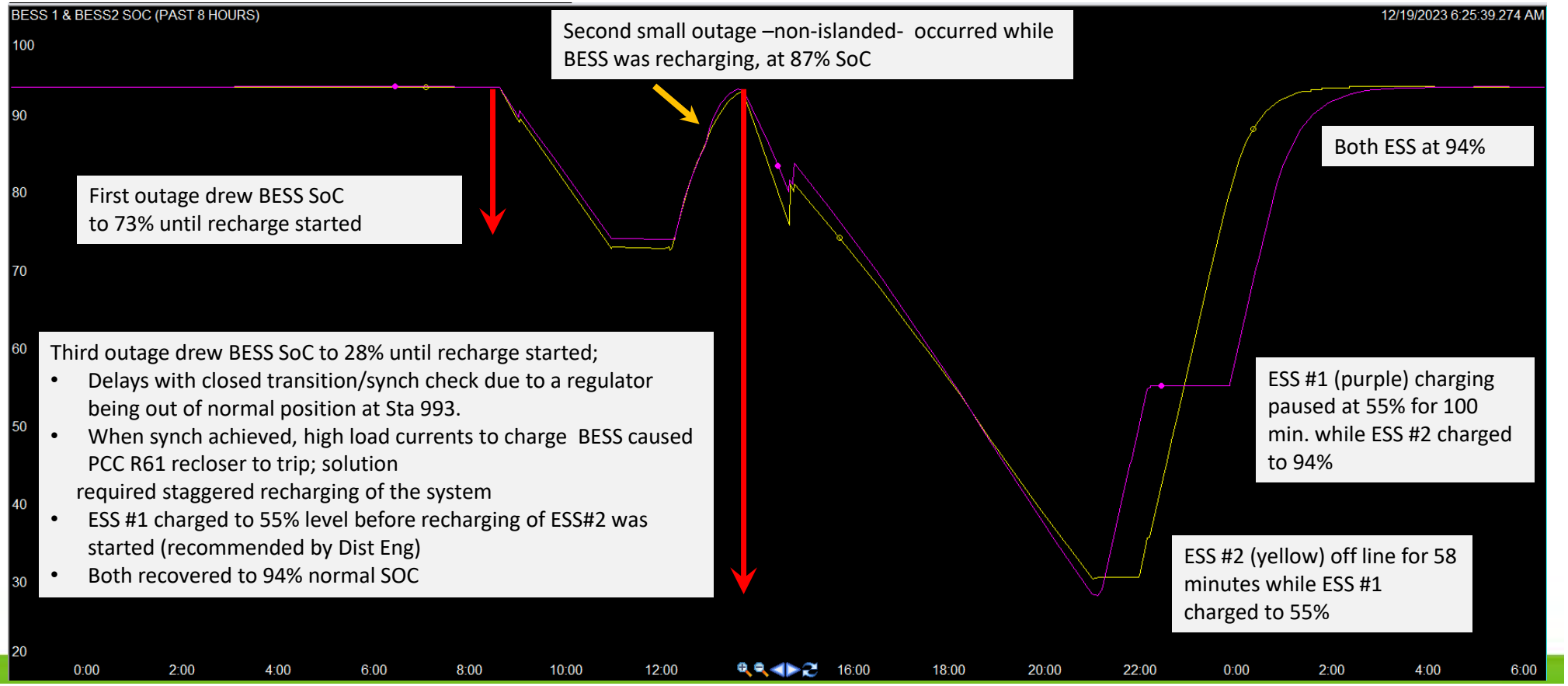
Stormy conditions during fault and extensive damage required over 6 hours for crews to repair pole top.



BESS Charge Levels Before, During and After 1st Island event

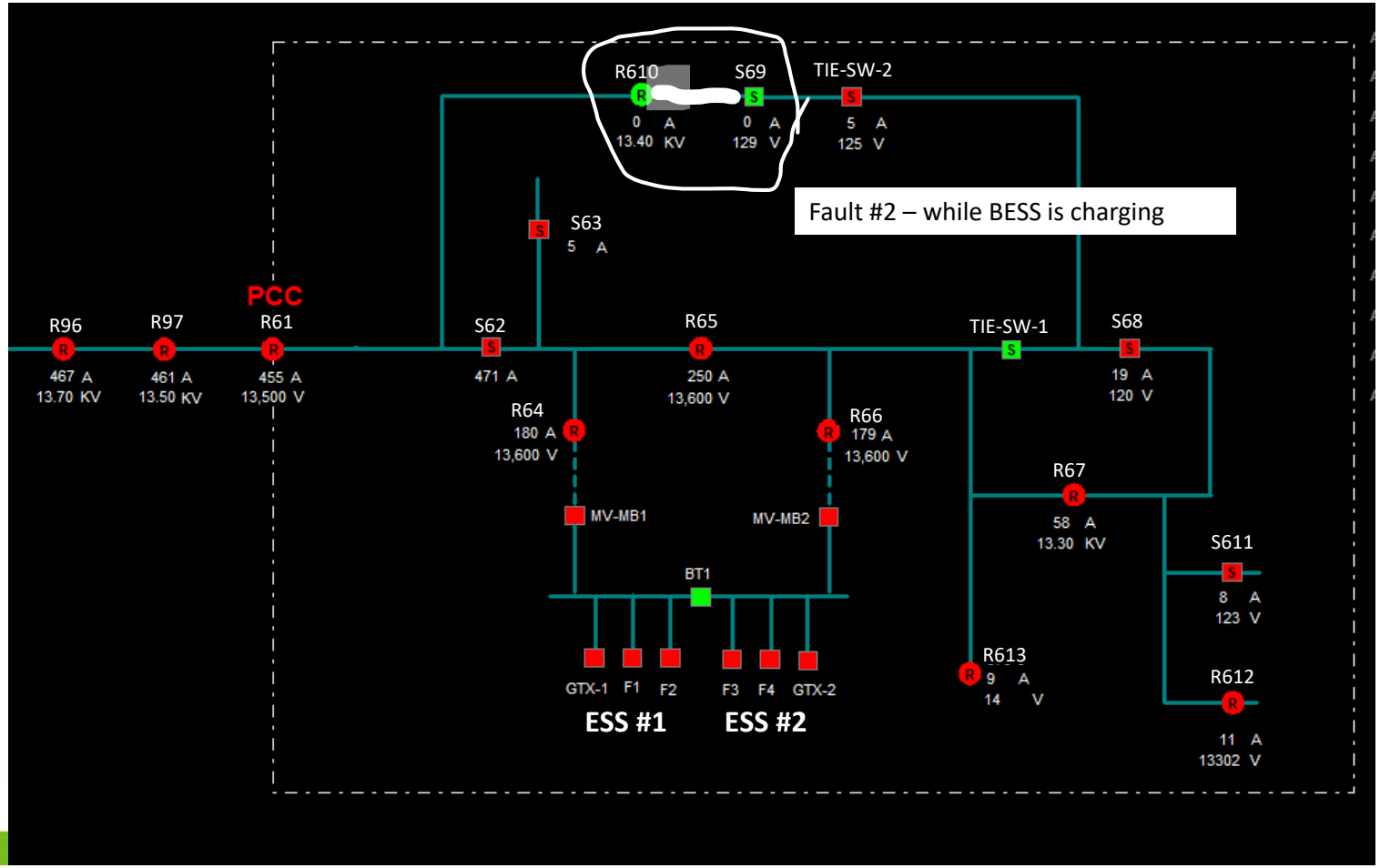


BESS Charge levels Surrounding Island Events 1 and 3



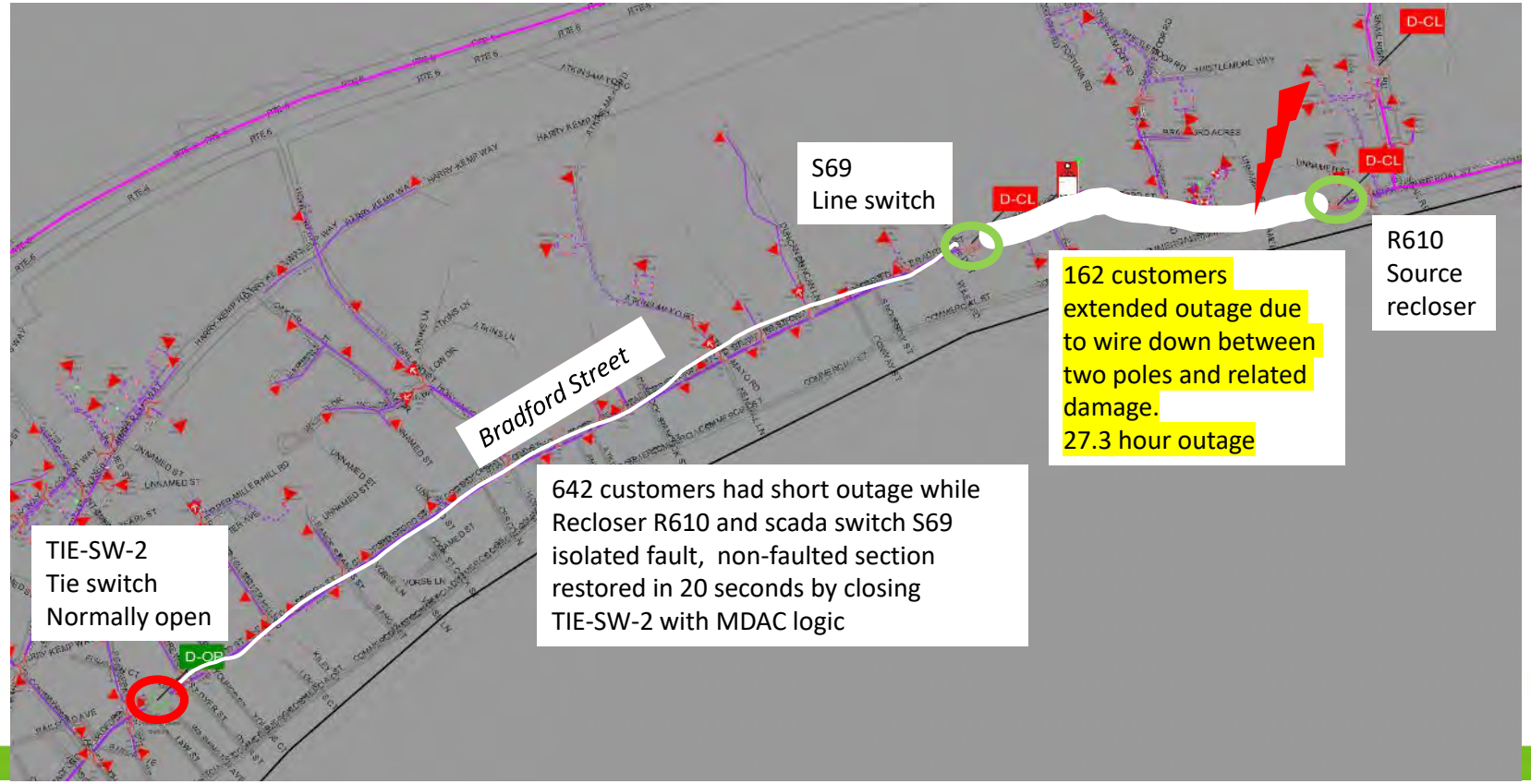
BESS Inrush Charging Current at 28% Soc Caused PCC R61 Recloser to Trip

- Up to 470A continuous on R61 to charge both ESS 1 and 2 and carry all Ptown load.
- Inrush and load current was higher and believed to cause R61 to trip open.
- Interim solution was to charge only one ESS at a time until they were both at 50% SoC.
- Settings changes were needed to reduce charge rate when system is heavily discharged or provide Dispatcher guidelines to only charge one ESS at a time.

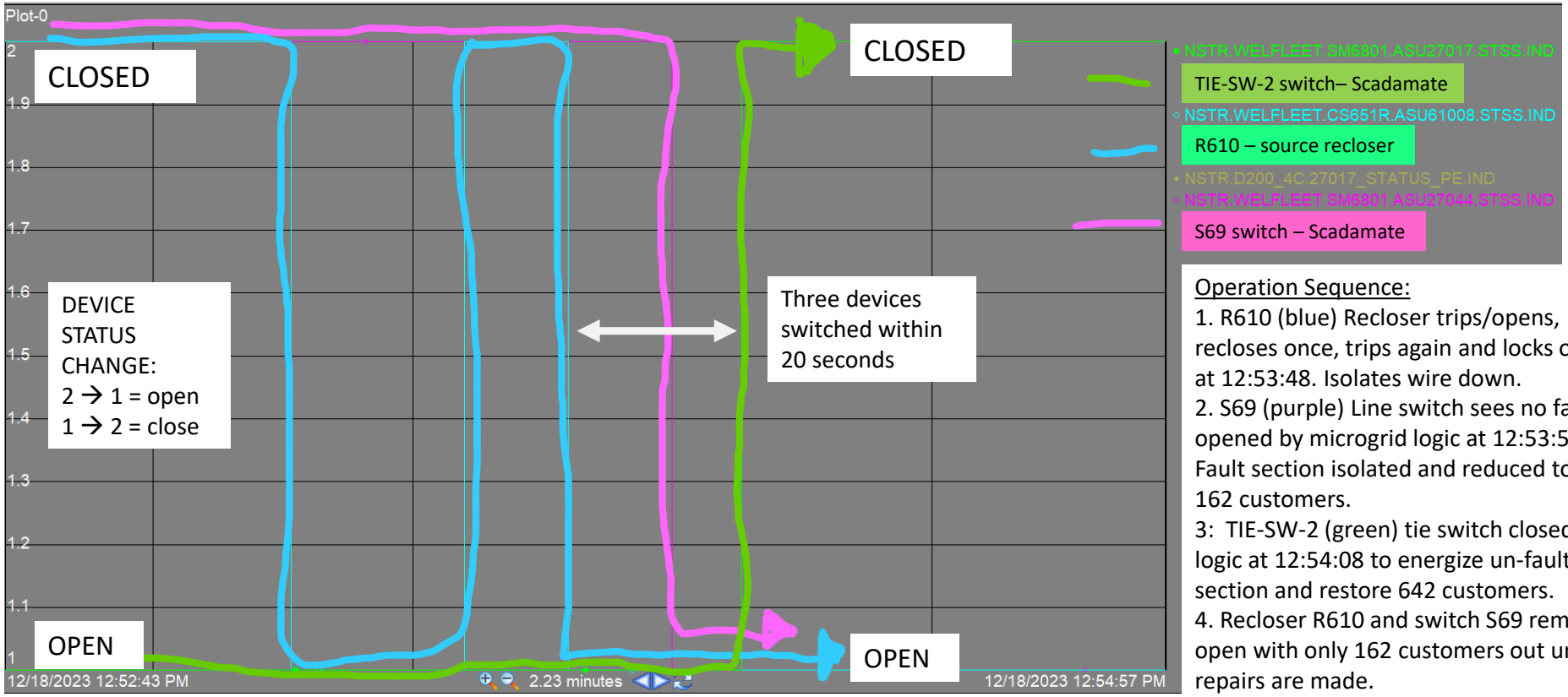


Fault #2: Circuit P6 wire down between S69 and R10

While the BESS was recharging, a primary wire down on Commercial St required recloser R610 to trip/reclose, and MDAC microgrid logic to isolate fault and minimize customer outage size in 20 seconds.



Fault #2 - Three devices isolate fault in 20 seconds – statuses in SCADA



Operation Sequence:

1. R610 (blue) Recloser trips/opens, recloses once, trips again and locks out at 12:53:48. Isolates wire down.
2. S69 (purple) Line switch sees no fault, opened by microgrid logic at 12:53:59. Fault section isolated and reduced to 162 customers.
3: TIE-SW-2 (green) tie switch closed by logic at 12:54:08 to energize un-faulted section and restore 642 customers.
4. Recloser R610 and switch S69 remain open with only 162 customers out until repairs are made.

Conclusions & Recommendations

1. BESS and Microgrid was able to carry the entire circuits P6 and W9 (10,050 customers) with no interruption during an open conductor, single phase fault. Reportable outage avoided for 9,917 customers for 42 minutes. Only 133 customers out for 42 minutes during repairs.

2. BESS and Microgrid effectively reduced impact of three primary faults with in a five hour period during a major storm.
   a. On two W9 circuit events, outage was avoided for 2 x 5,662= 11,324 customers due to MDAC and transfer trip of the PCC and immediate load island forming in Provincetown. This impacted only 2 x 611= 1,222 customers in the damaged wire zone.
   b. On one P6 circuit smaller event, MDAC logic reduced outage time for 642 customers to 20 seconds. Impacted 162 customers for extended period of 27 hours until repairs were made.

3. There was some difficulty synchronizing the BESS island back to the grid because a single phase North Truro regulator was not regulating Voltages in line with the other two units. Closed transition was almost not possible due to voltage differences across the open recloser.
   a. Solution is to add SCADA control and visibility to three regulators to allow Dispatcher remote control.
   b. Back up solution was to reconnect Provincetown island with an open transition (short outage) if synchronization was not possible.
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4. Appears that the BESS fast charging rates and moderate loading on line circuit P6 caused the R61 PCC recloser to trip when reconnected and charging at a 28% SoC.
   a. Evaluate and revise charging currents/rates to prevent unnecessary tripping.
   b. Update Dispatcher instruction to allow for only charging one ESS at a time.