Data Center Modeling and Associated CMLD Data

WECC Modeling and Validation SC Meeting

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Contents

- Consultant supplied PSCAD model of crypto mine
- Data center use of CBEMA/ITIC graphs
- May 5, 2023 fault event near data center
- Observations/Modeling Variables
- Data center UV dropout

One Crypto Miner’s Replies to Initial Version of Questionnaire
(their Consultant also devised a PSCAD model for SSO study purposes)

Cooling Load

- The cooling in our data centers relies on forced air fans fed by variable speed drives
- There is no HVAC
- The consultant supplied PSCAD model PQ load component is the cooling load (about 7 percent of total)

Electronic Load

- A protection mechanism begins to drop load as voltage goes below 0.8 pu and drops load to 0 as voltage goes below 0.5 pu
- There is no UPS/battery system
- The consultant supplied PSCAD model indicates that the computer system loads drop to 0 instantaneously as the voltage drops below 50% and reconnects instantaneously as the voltage crosses 50%
- The PSCAD model assumed three-phase rms for the load dropping function since not enough information was available from the crypto miner manufacturer
- The PSCAD model measures Vrms and reduces load accordingly as the Vrms level increases or decreases

Further Observations from PSCAD Model

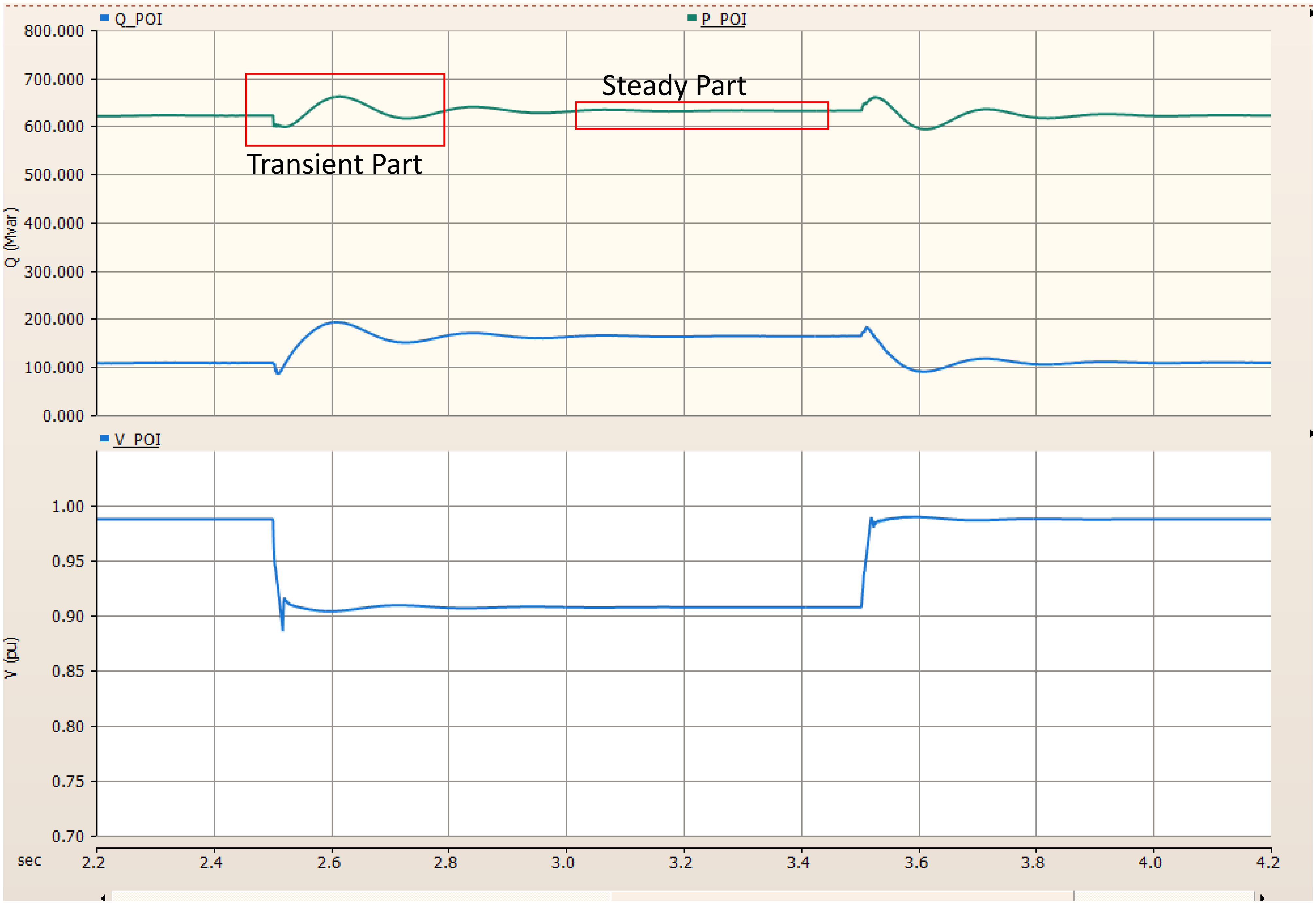
- The UPSs have active front end which means they draw more current from the grid during voltage dips to maintain dc bus voltage (until disconnected)
- Behavior is different than most VSI drives which are diode/passive front end

- Transient behavior is current control action with lag which, when multiplied by voltage, gives the power behavior
  - This causes power to dip as voltage decreases and rise as current rises to charge dc bus
- This transient behavior has an oscillatory component, which cannot be captured by CMLD (We need to investigate if this is consequential, given the loads are large)
  - This oscillatory behavior occurs when terminal voltage lingers around 0.8 pu and the crypto UPS switches between constant power and constant current type behavior (Need to confirm with the load owner if this happens in reality or is a modeling issue)

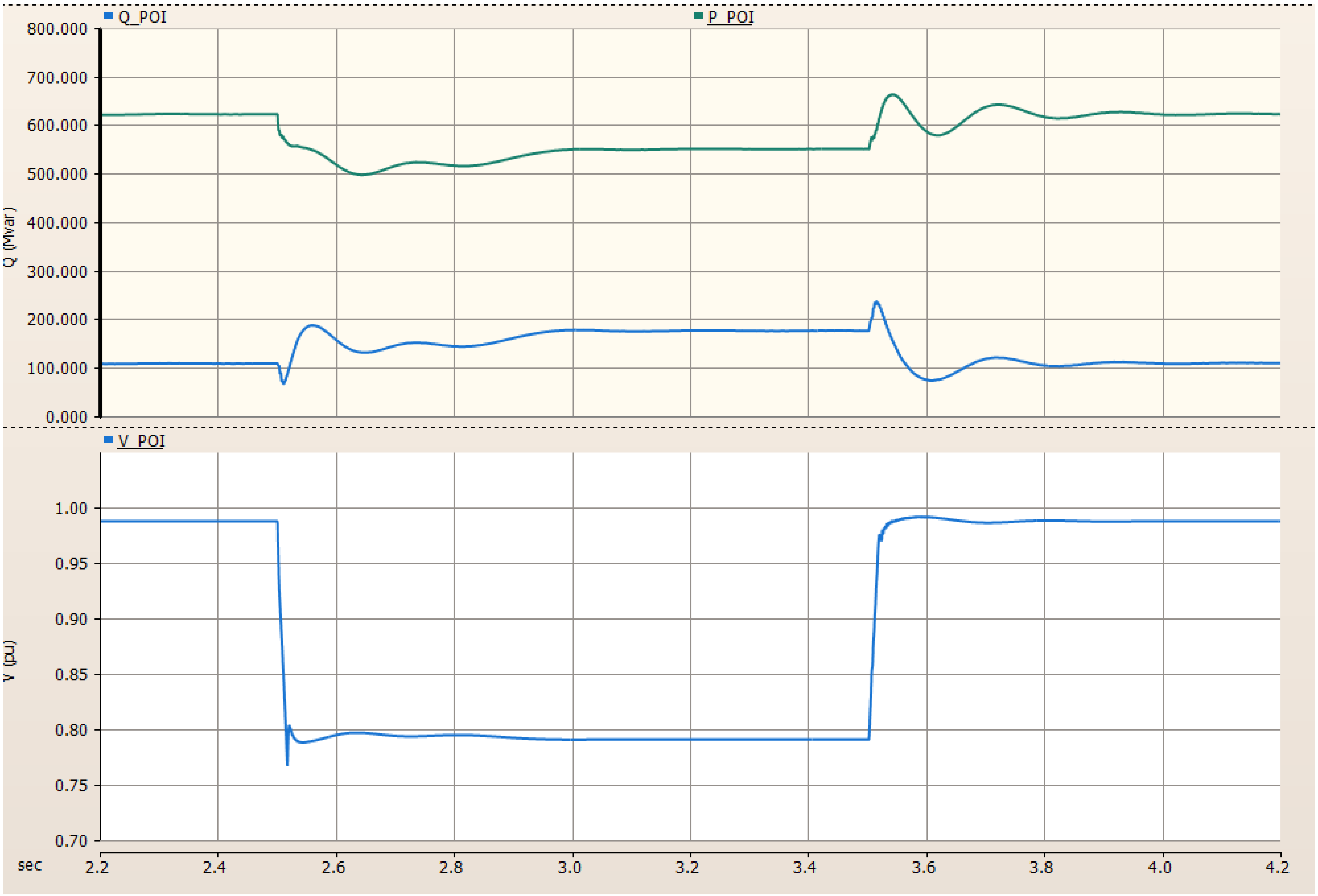
- In steady-state, the data center active power acts as
  - Constant Power for 0.8 pu < voltages
  - Constant Current for 0.5 pu < voltages < 0.8 pu
  - Disconnects for voltages < 0.5 pu
- The electronic load does not consume reactive power during low voltages but increased current causes reactive losses and therefore reactive power consumption to rise

Consltnt supplied PSCAD Model

10% Sag

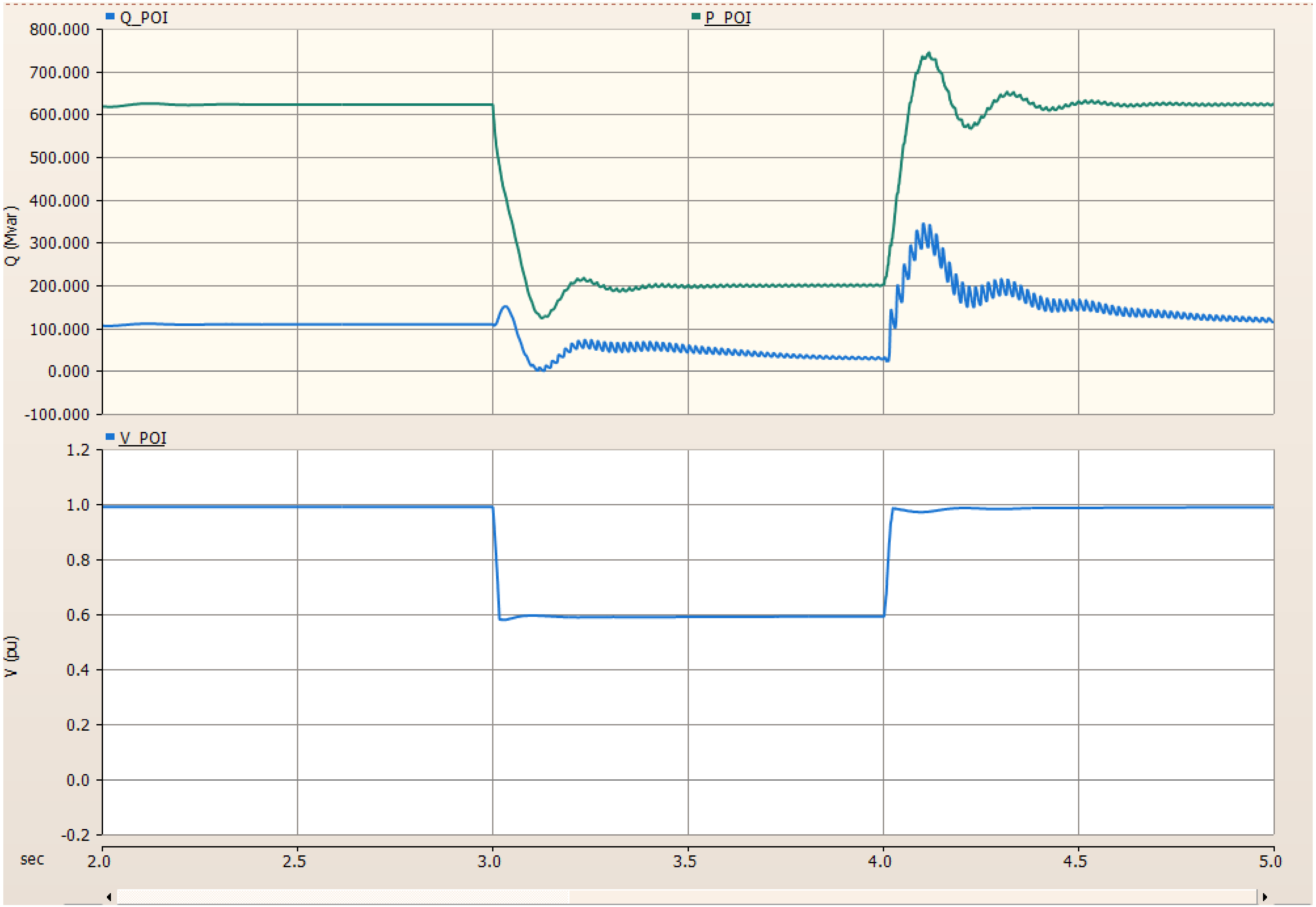


20% Sag

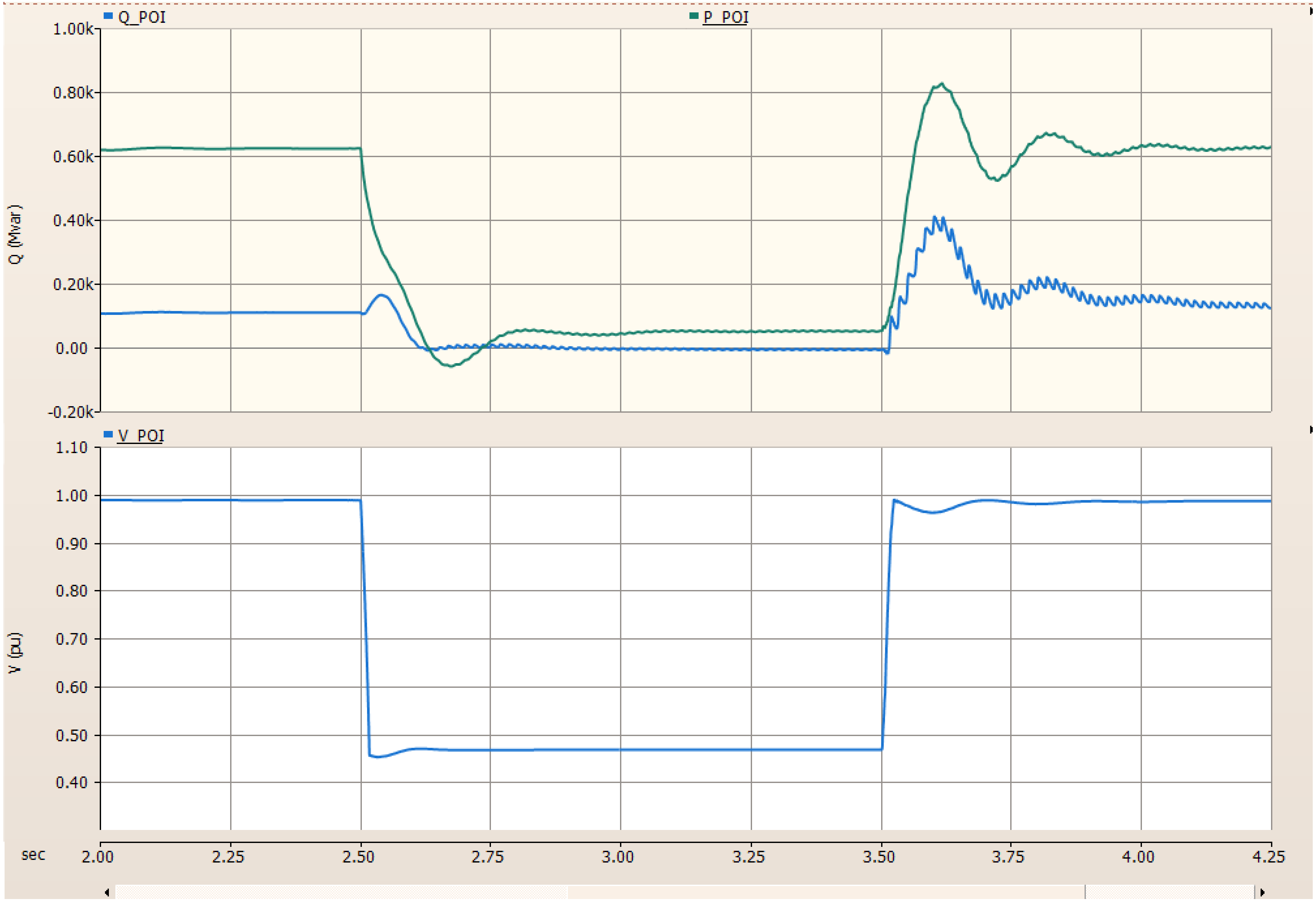


Q_POI
P_POI
800.000
700.000
600.000
500.000
400.000
300.000
200.000
100.000
0.000
Q (Mvar)
V_POI
1.00
0.95
0.90
0.85
0.80
0.75
0.70
V (pu)
sec
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
4.2

40% Sag


Q_POI
P_POI
800.000
700.000
600.000
500.000
400.000
300.000
200.000
100.000
0.000
-100.000
Q (Mvar)
V_POI
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
V (pu)
sec
2.0
2.5
3.0
3.5
4.0
4.5
5.0

50% Sag

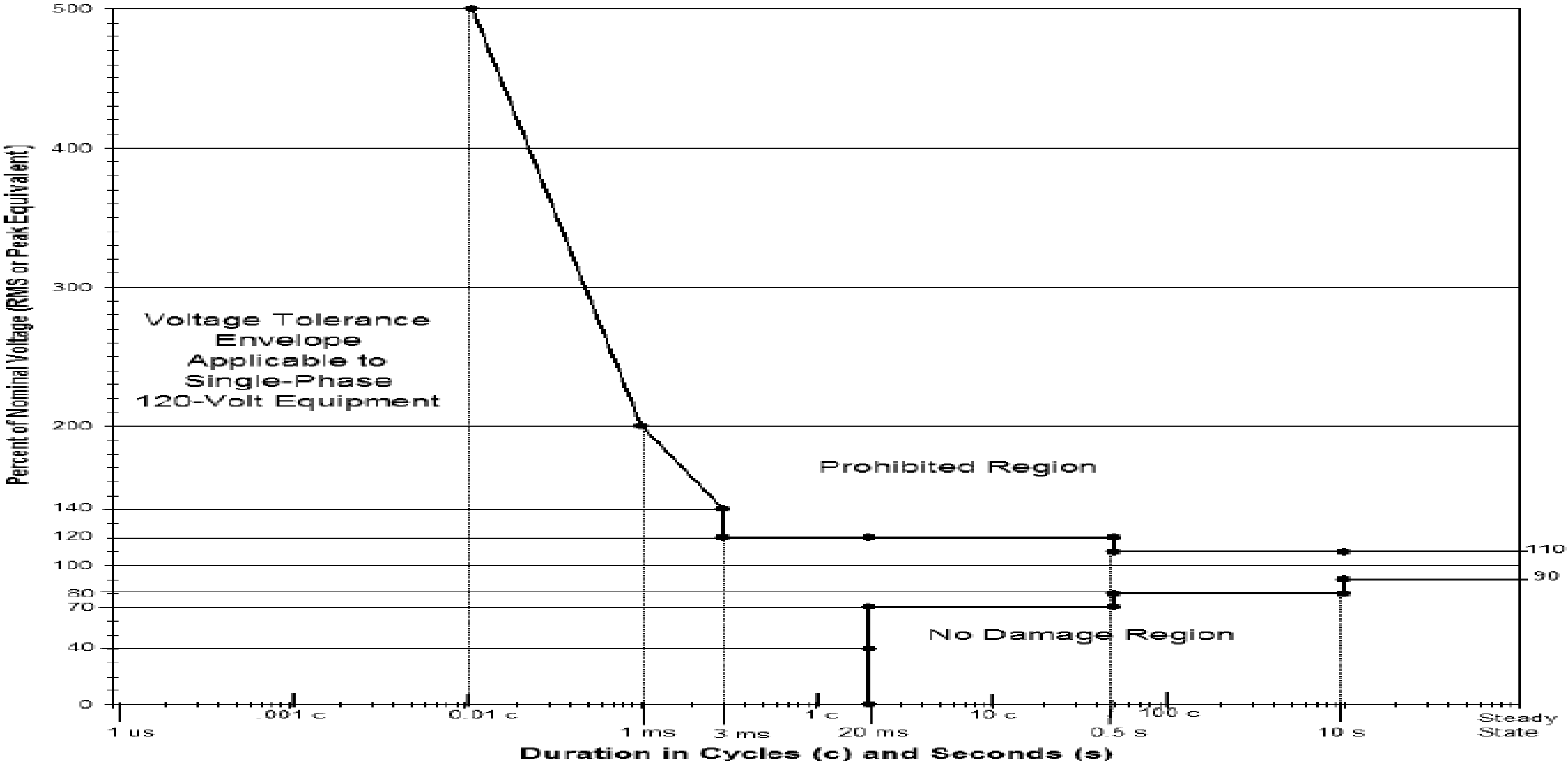


Q_POI
P_POI
1.00k
0.80k
0.60k
0.40k
0.20k
0.00
-0.20k
Q (Mvar)
V_POI
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
V (pu)
sec
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
4.25

Data Center use of CMEBA/ITIC Graphs for Over- and Under-Voltage Protection?

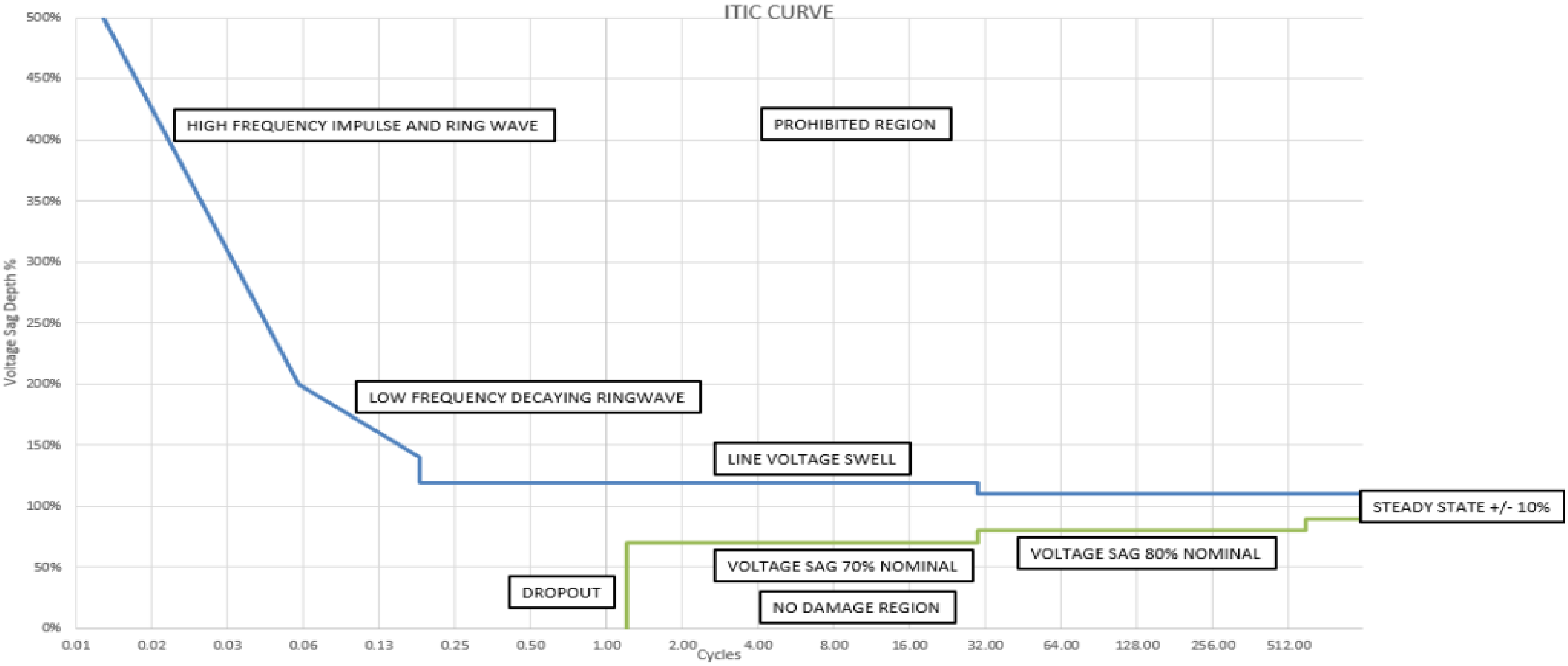
Note: These graphs are not design standards and were never intended to apply to data centers, only as guide to small electronic appliance expectations on UV dropout and damage

CBEMA / ITIC Graph #1



New ITI Curve (CBEMA) Curve (2000)

CBEMA / ITIC Graph #2



ITIC CURVE

AEP Experience with Data Center Loads to Date

- Several dynamic studies run on data center interconnections, as required by RTO, have shown no stability or dynamic issues
  - Steady-state studies generally sufficient to identify system impacts
- LMWG generic data center CMLD data aligns well with project specific data received from a few data center interconnections
  - Except for UV dropout, interesting dynamic characteristics, such as we have found with motor D, seem generally absent
- However, when near series caps and once radial, SSO studies tend to show SSFR involving data center transformers when data center load is off or low

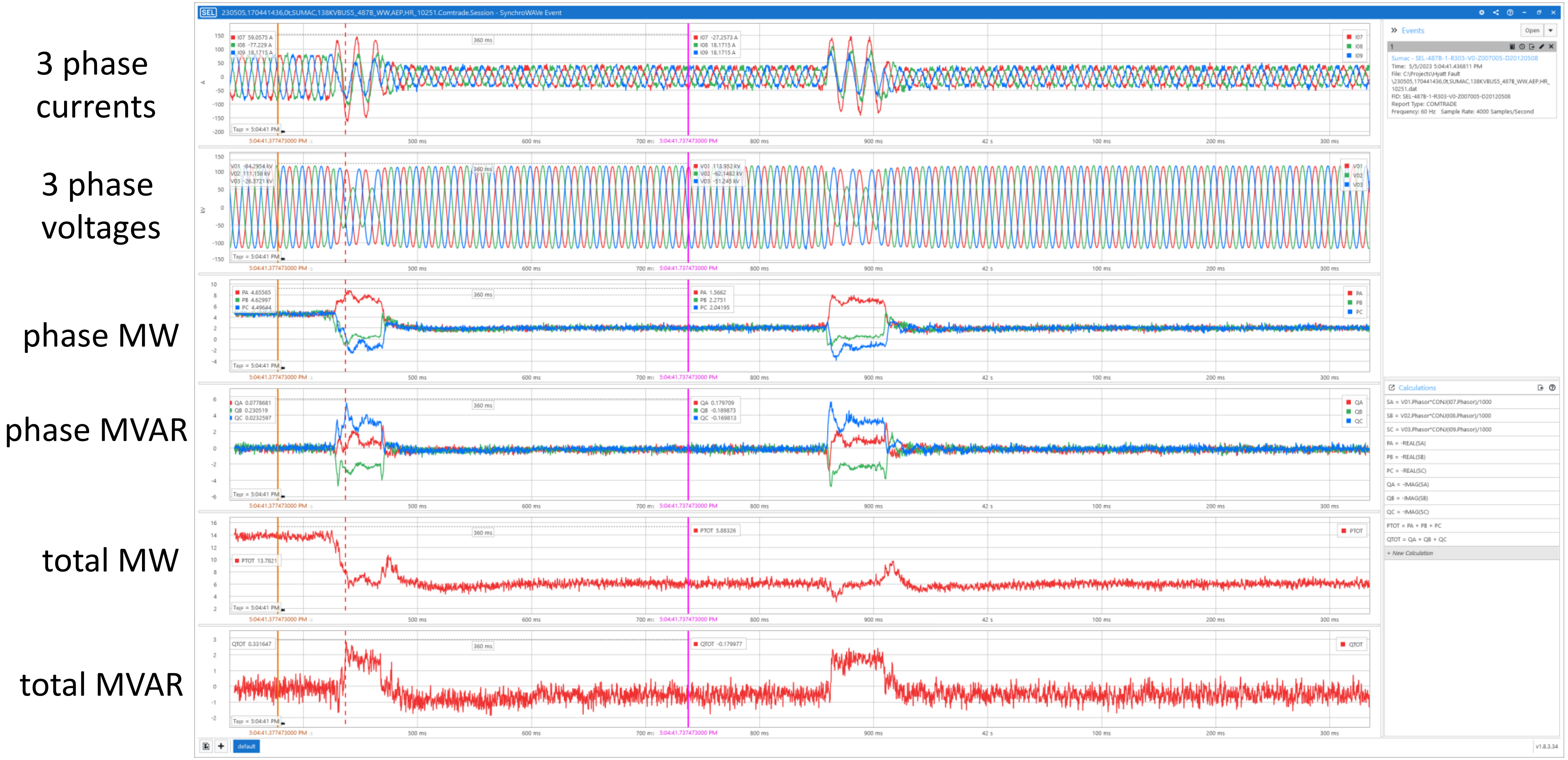
An event on May 5, 2023 involving series of phase-ground faults (initial fault and three unsuccessful reclose attempts) near a data center

- Phase-ground fault on a line arrestor at nearby 345 kV station
- High-speed reclose in 25 cycles
- 1st timed reclose 5.2 seconds from initial fault
- 2nd timed reclose 15.6 seconds from initial fault

- Nine data center individual transformer relay event records at two AEP 138 kV stations serving ______ data center show varying responses from significant reductions in load to no reduction in load

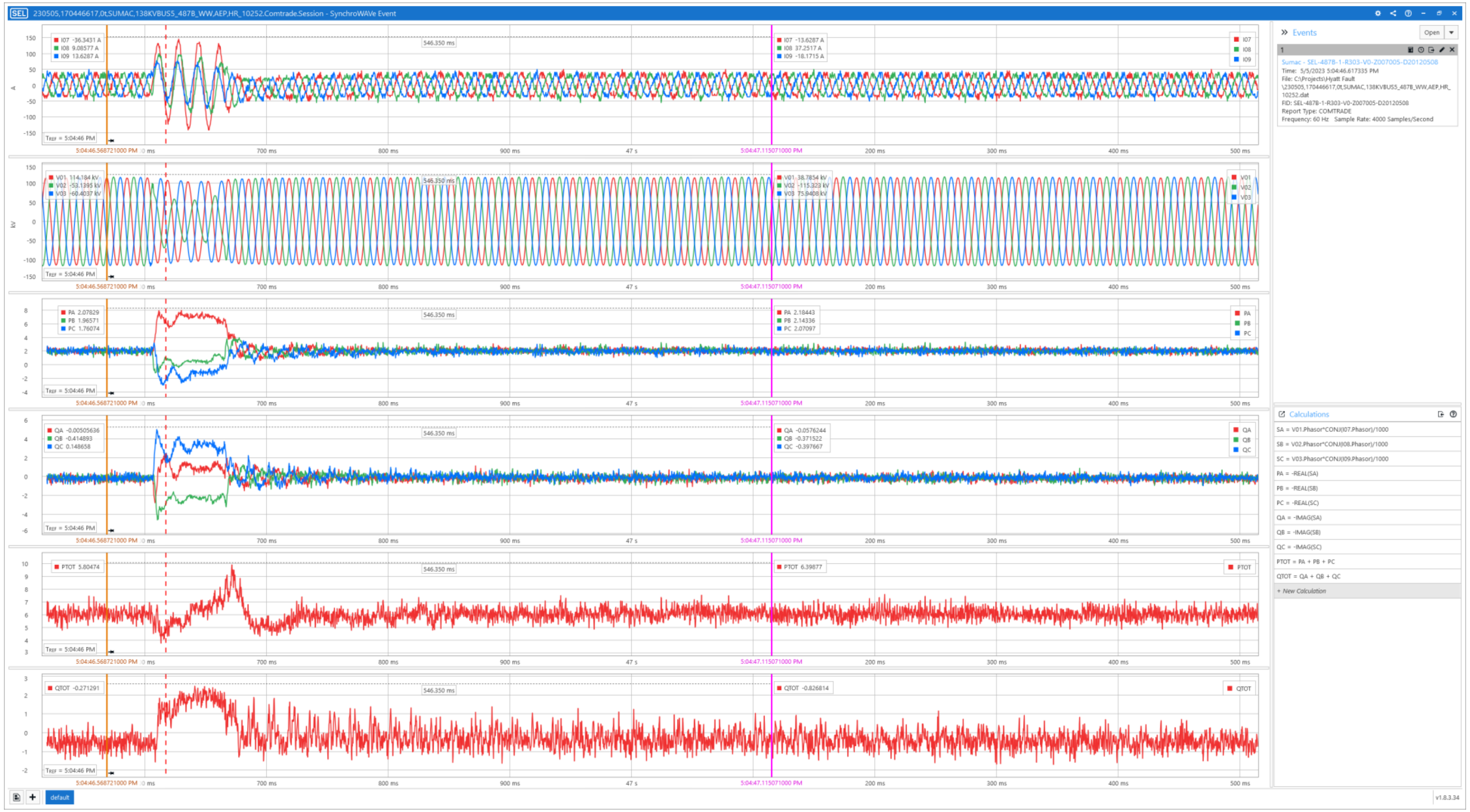
MM Station XF 4 – Initial and high-speed reclose

Active power decrease from 14 MW to 6 MW



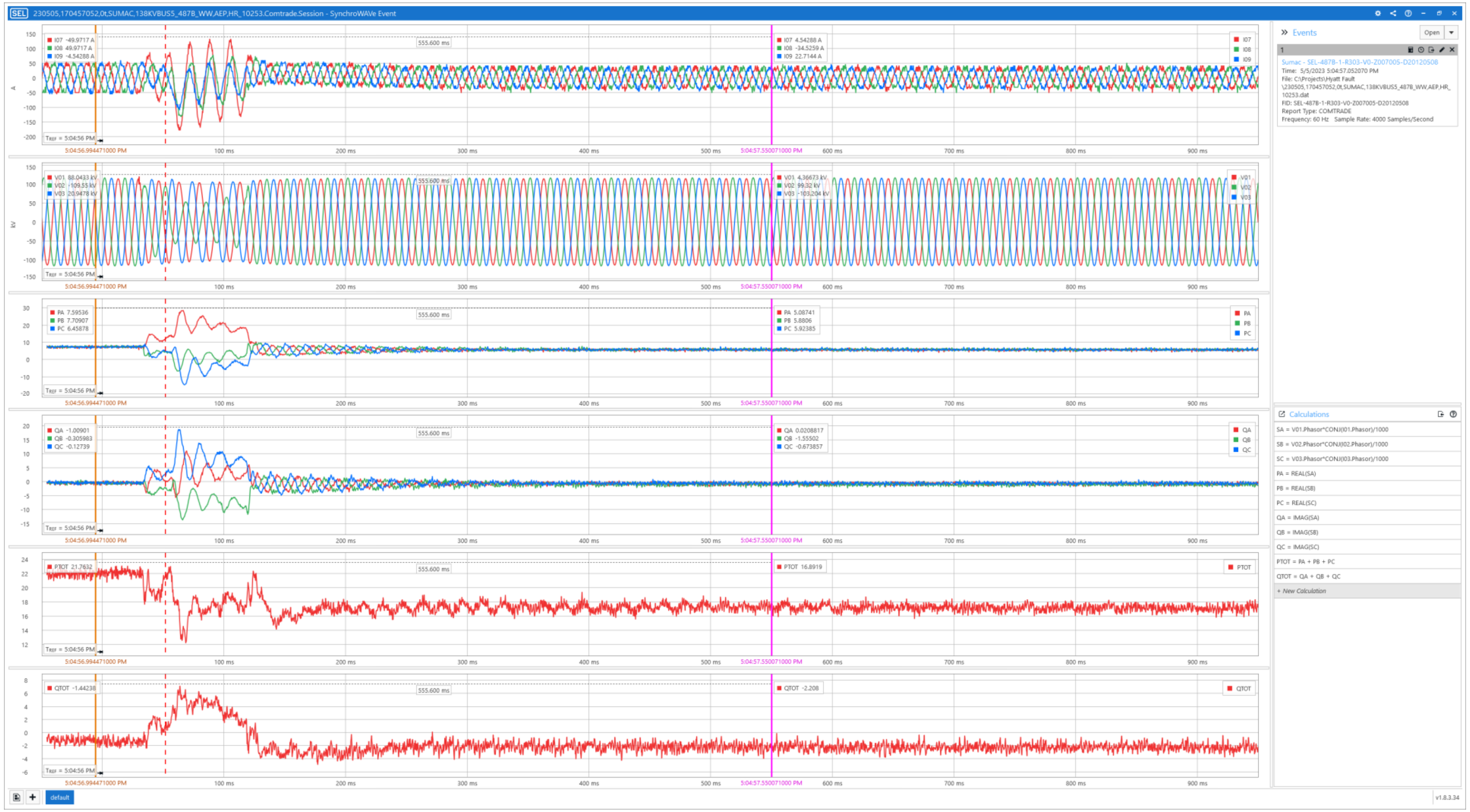
MM Station XF 4 – 1st timed reclose

Active power remains at 6 MW



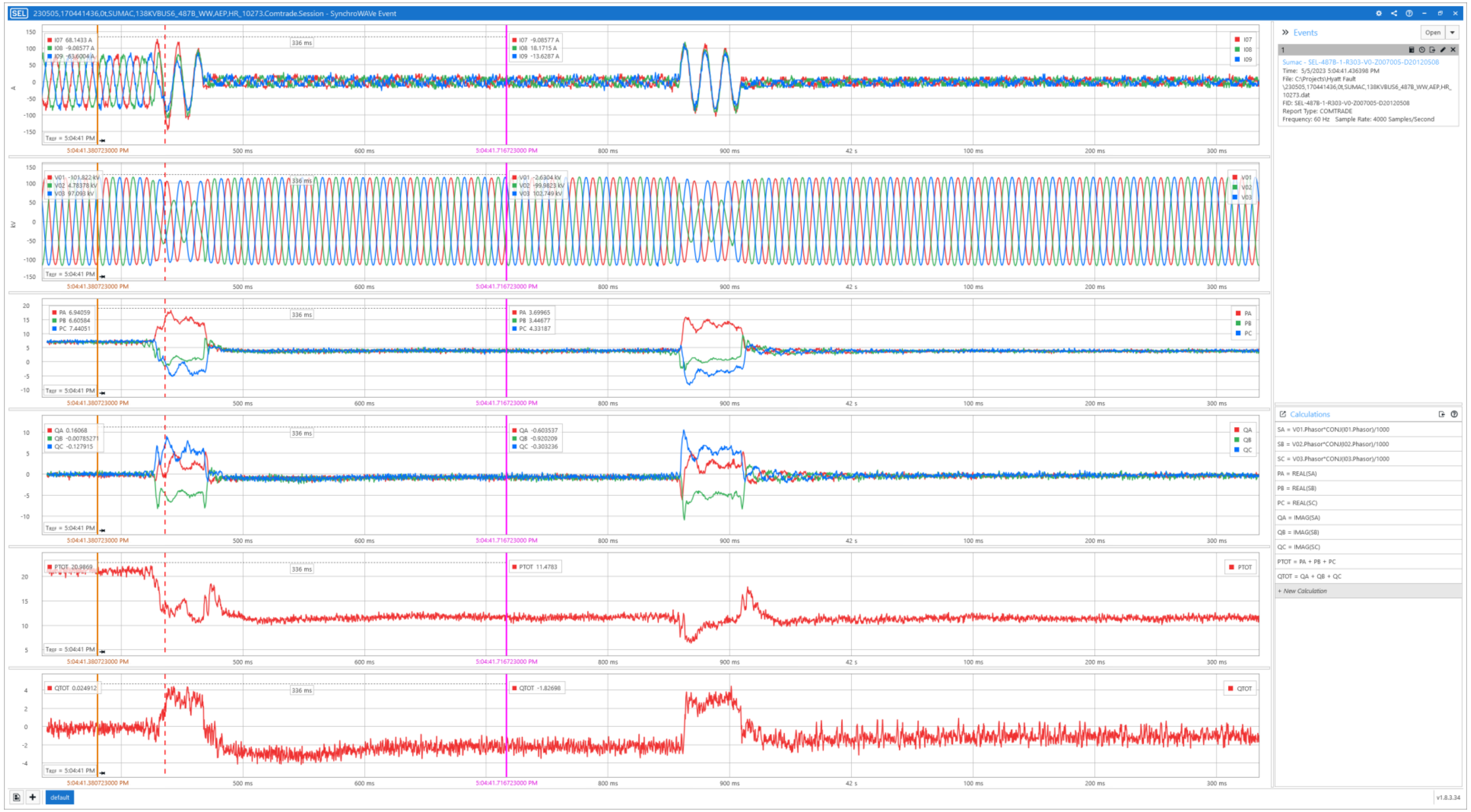
MM Station XF 4 – 2nd timed reclose

Active power increased to 22 MW in interim then decreases to 17 MW



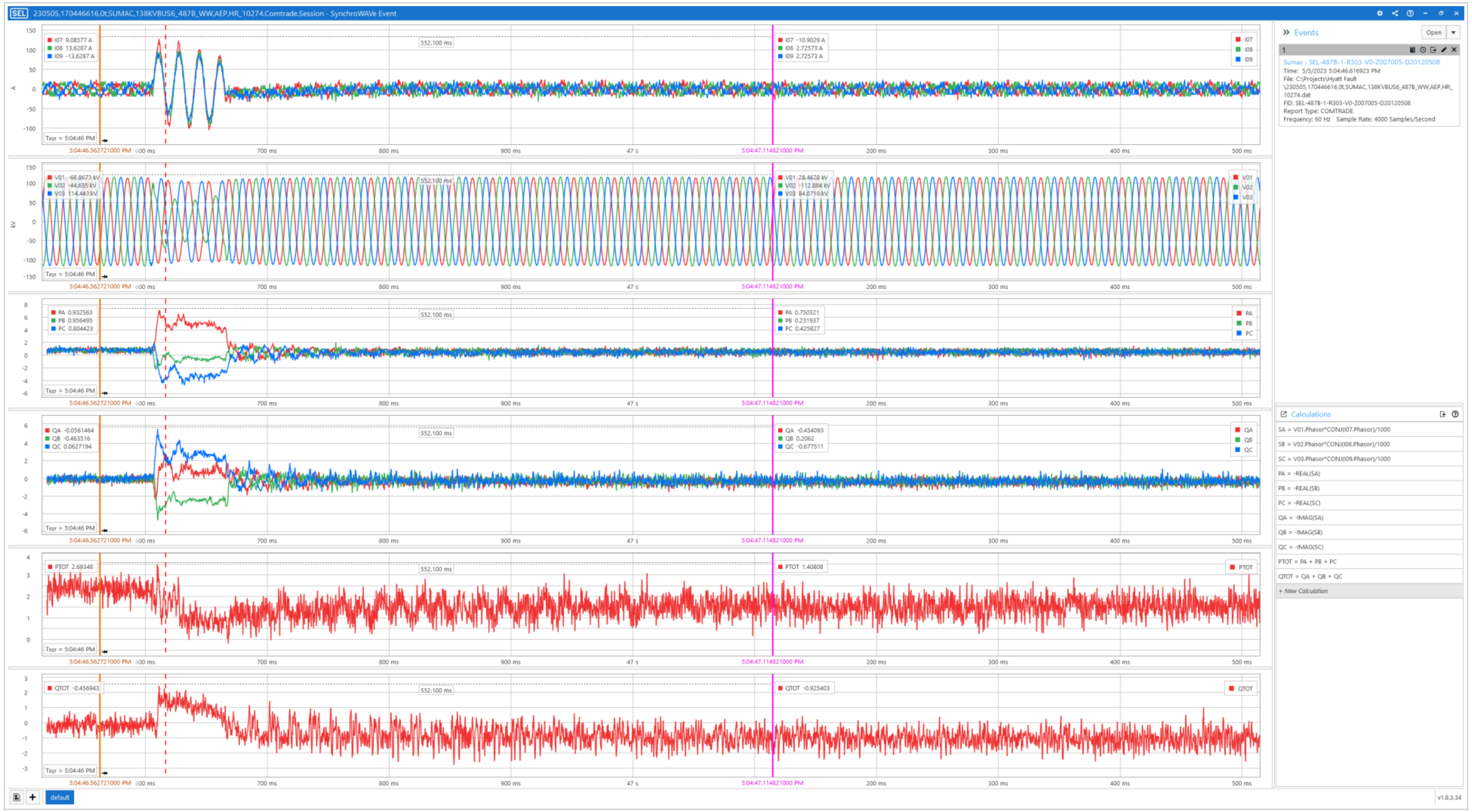
MM Station XF 5 – Initial and high-speed reclose

Active power decrease from 22 MW to 12 MW



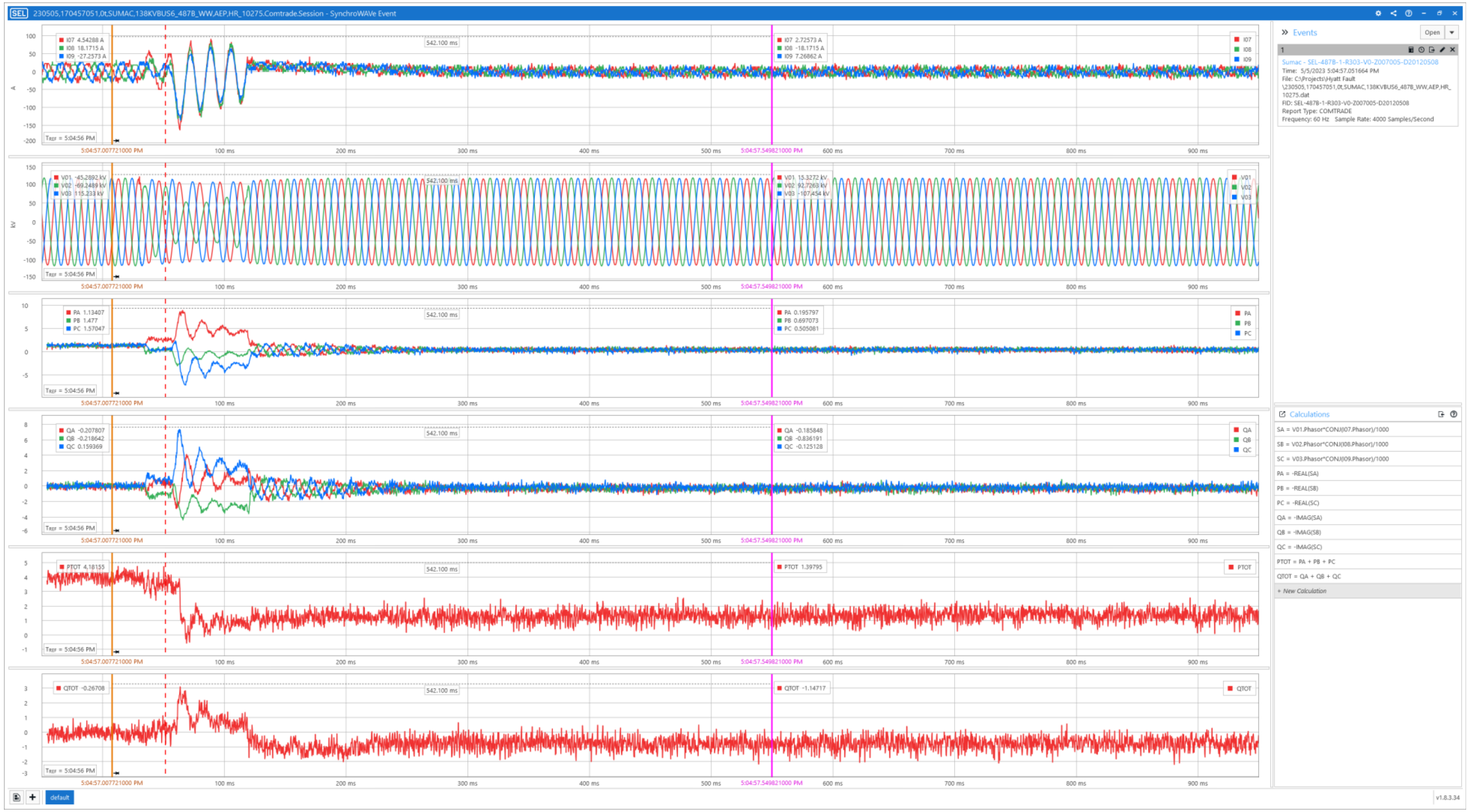
MM Station XF 5 – 1st timed reclose

Active power decrease from 2.5 MW to 1.5 MW



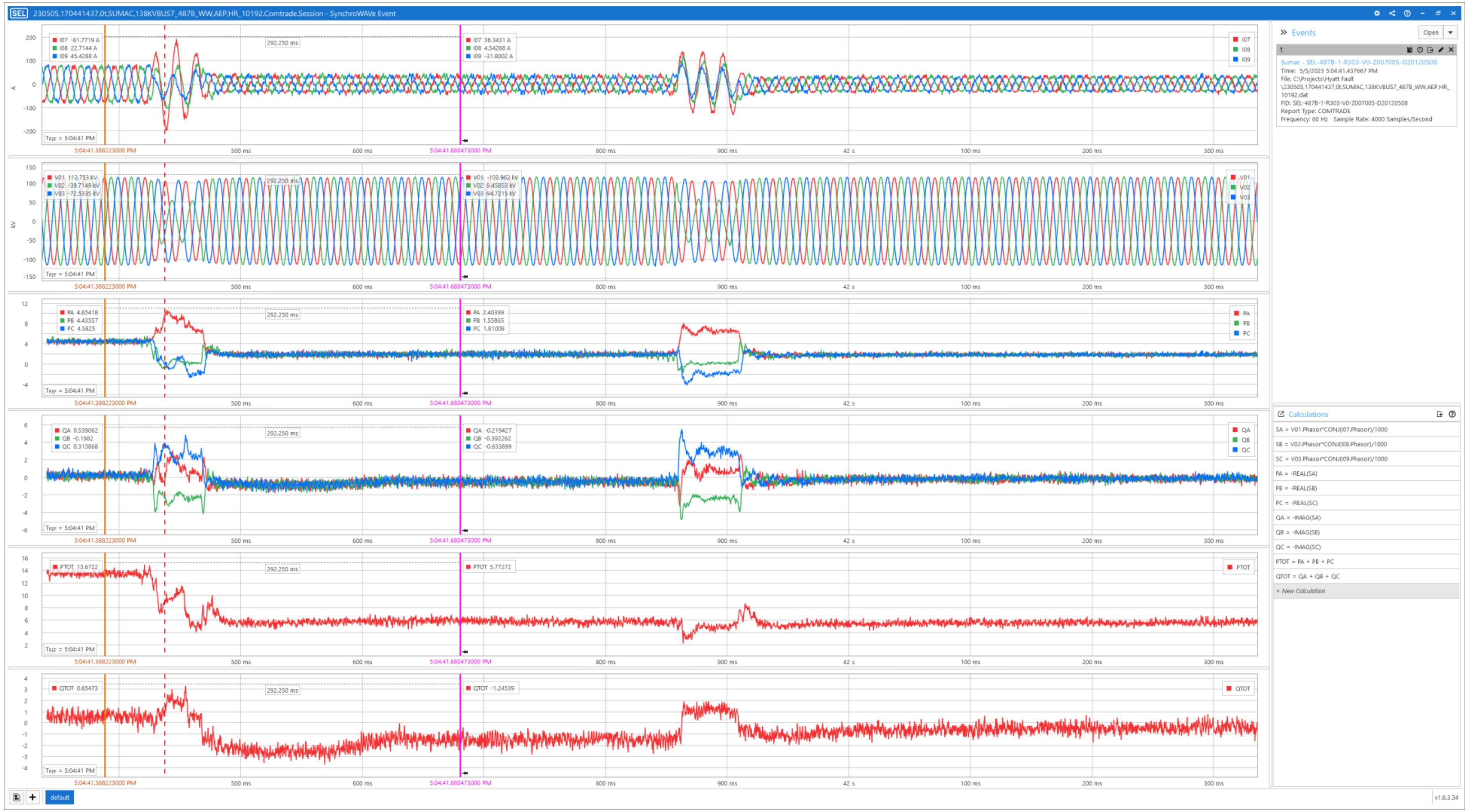
MM Station XF 5 – 2nd timed reclose

Active power decrease from 4 MW to 1 MW



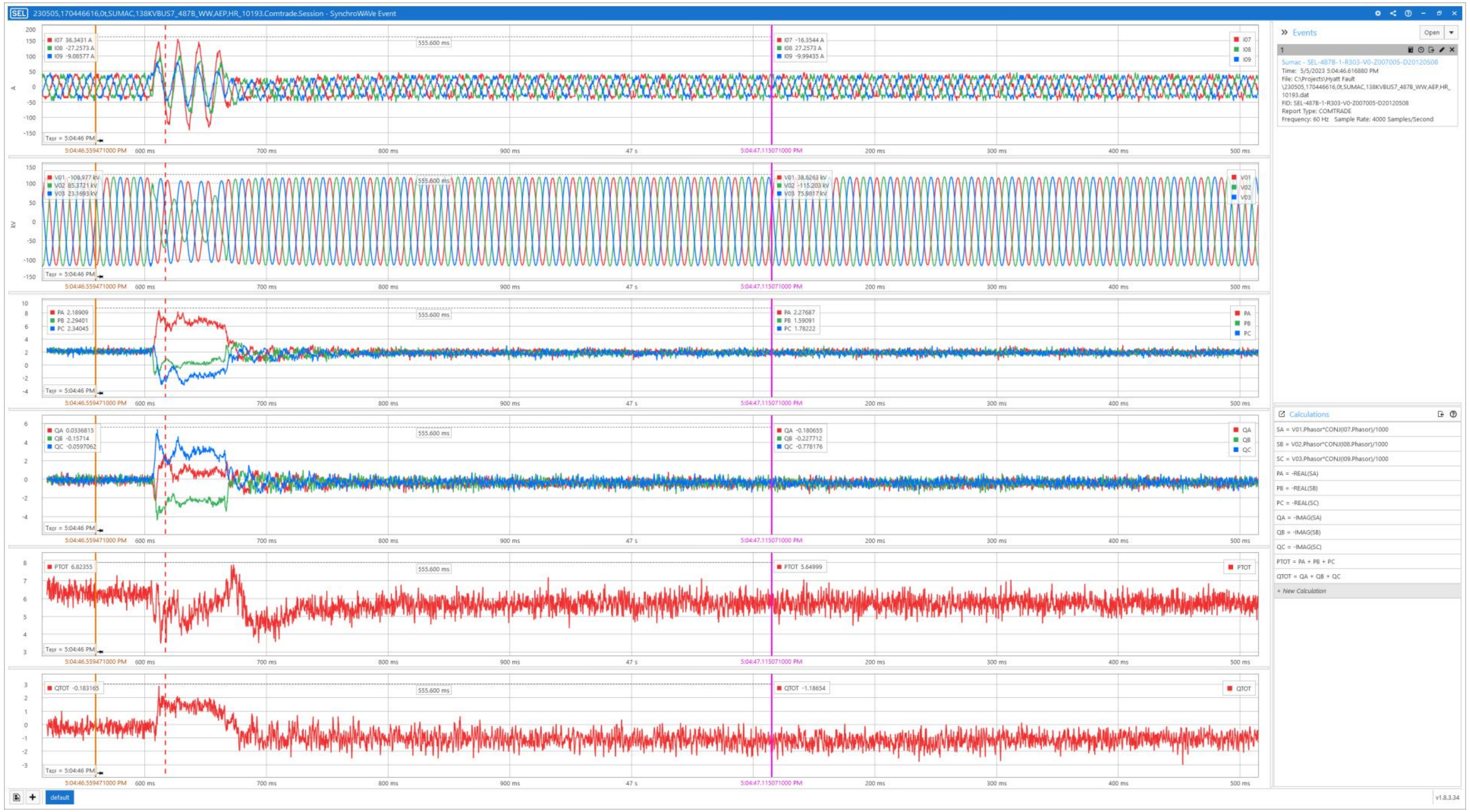
MM Station XF 6 – Initial and high-speed reclose

Active power decrease from 13 MW to 6 MW



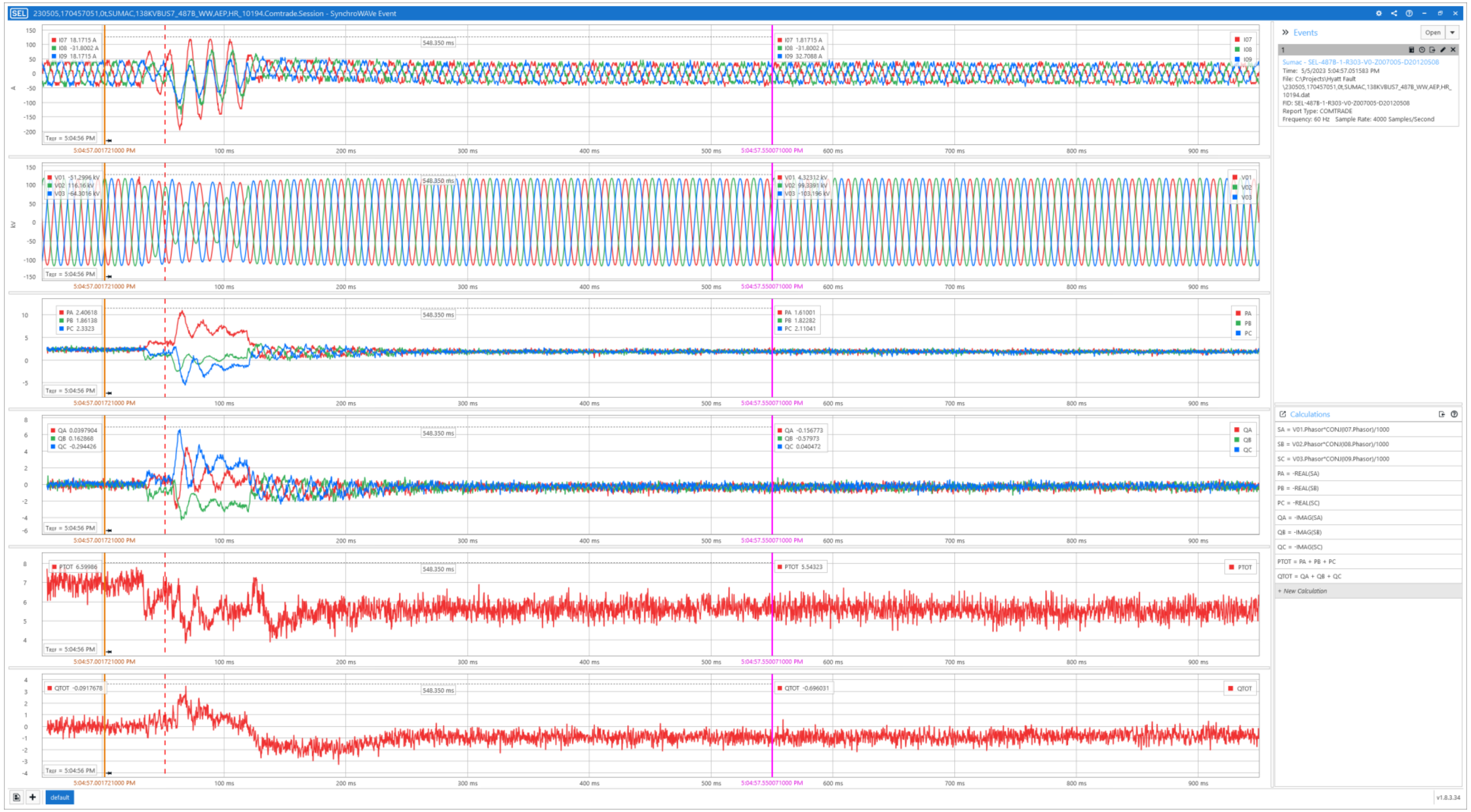
MM Station XF 6 – 1st timed reclose

Active power decrease from 6.5 MW to 5.5 MW



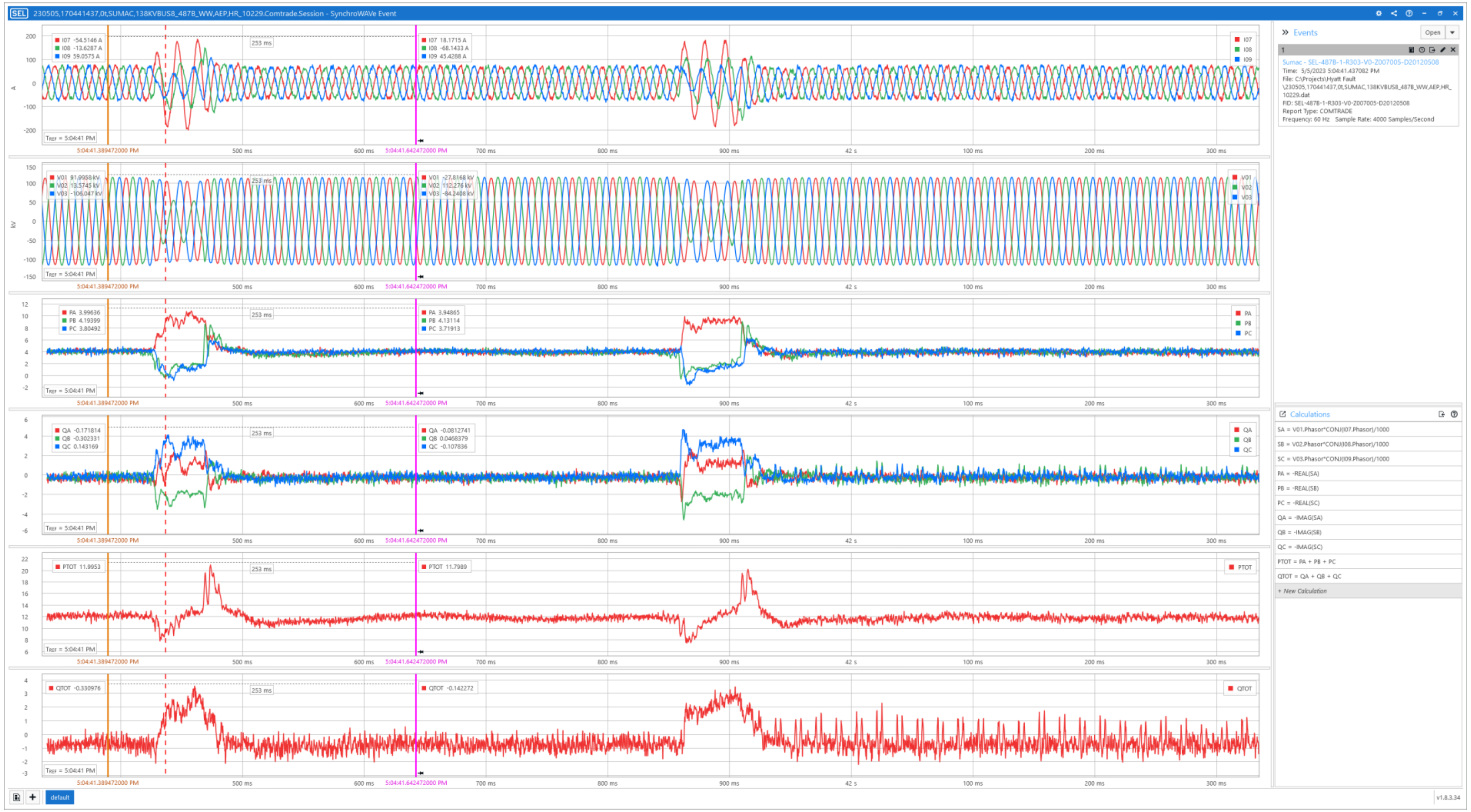
MM Station XF 6 – 2nd timed reclose

Active power decrease from 7 MW to 5.5 MW



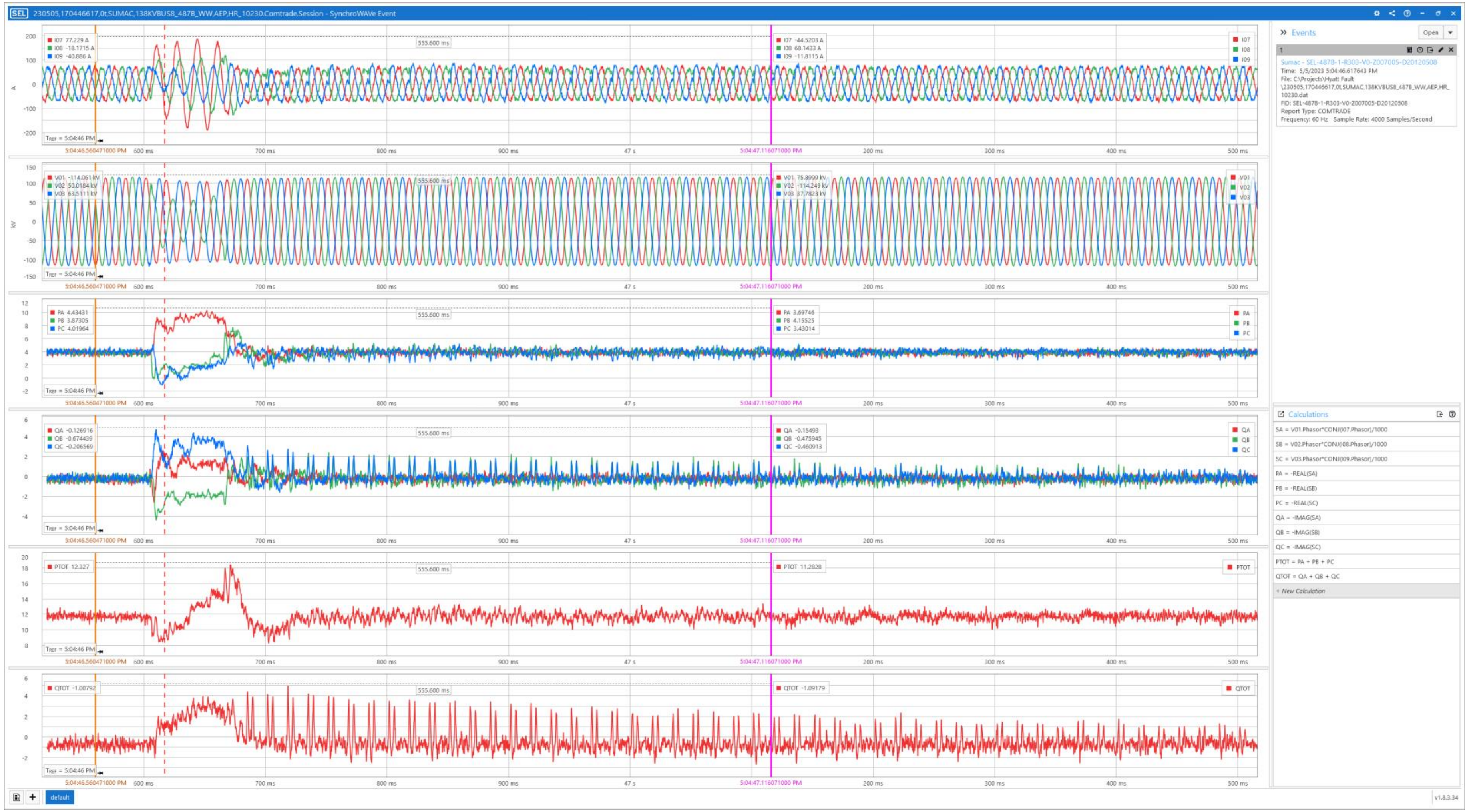
MM Station XF 7 – Initial and high-speed reclose

Active power stays about 12 MW



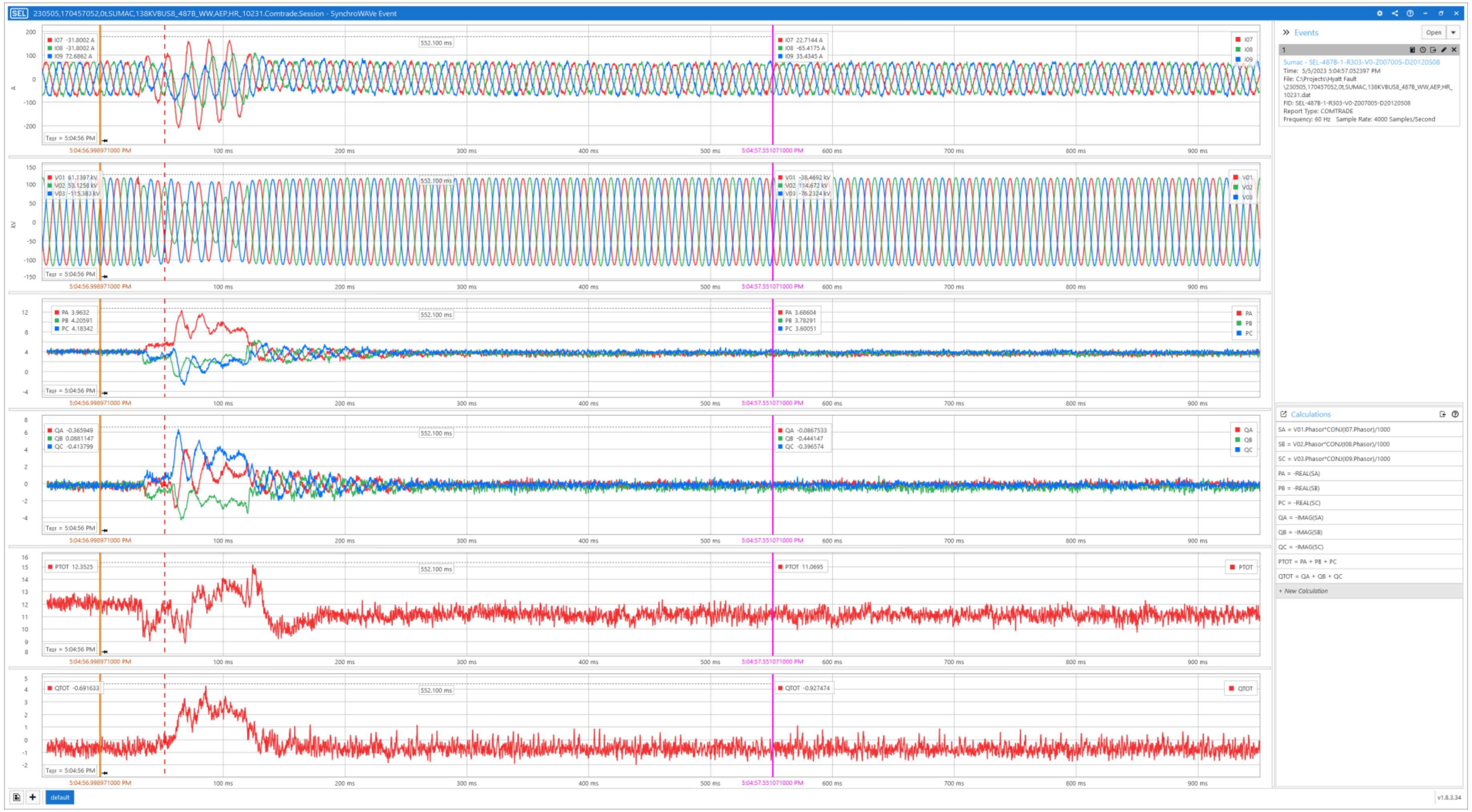
MM Station XF 7 – 1st timed reclose

Active power stays about 12 MW



MM Station XF 7 – 2nd timed reclose

Active power stays about 12 MW



MM XF 8 – similar to MM XF 7

<u>SM Station Data Center Transformers:</u>

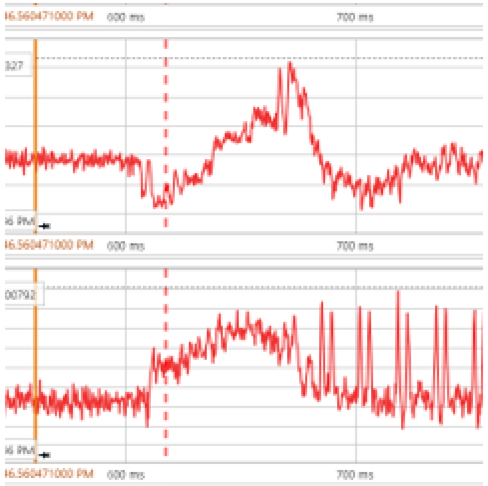
	FLT		HSR		1^{st}RCL		2^{nd}RCL		
SM XF 1	13	–>	6	–>	6	–>	7	–>	6 MW
SM XF 2	13	–>	2	–>	1	–>	3.5	–>	1.5 MW
SM XF 3	13	–>	6	–>	6	–>	6	–>	5.5 MW
SM XF 4	8	–>	8	–>	8	–>	8	–>	8 MW
SM XF 5	9	–>	9	–>	9	–>	9	–>	9 MW

Observations/Modeling

- LMWG default CMLD data center data seems consistent with steady-state behavior in event records and PSCAD model
- Transient behavior present in both event records and PSCAD model but of minimal magnitude; CMLD cannot replicate at present
- Some of the event records indicate active control of a DC bus during sags:

MW

MVAR



Observations/Modeling, continued

Modeling Variables:

- UV dropout behavior is clearly a variable
- LMWG default CMLD data center data component breakdown seems consistent with event records and PSCAD model
  - CMLD default: 90% constant P/Q with UV dropout; 10% motor C
- May 5, 2023 event records show slight leading PF operation on all nine transformers; PSCAD model shows slight lagging PF operation (.986)

Anticipated Data Center Modeling Issue: UV Dropout

Because these loads can be sizable, and because they are tending to congregate in certain areas, the following are three system impacts anticipated:

1. Over-frequency events caused by multiple data center trips in response to faults and other system disturbances
2. Over-voltage events caused by same if mechanically switched caps are applied to maintain service to data centers
3. Instability of stability constrained areas within which, or near which, data centers are located caused by sudden increase in area generation net of load