



Air Conditioner Stalling Solutions

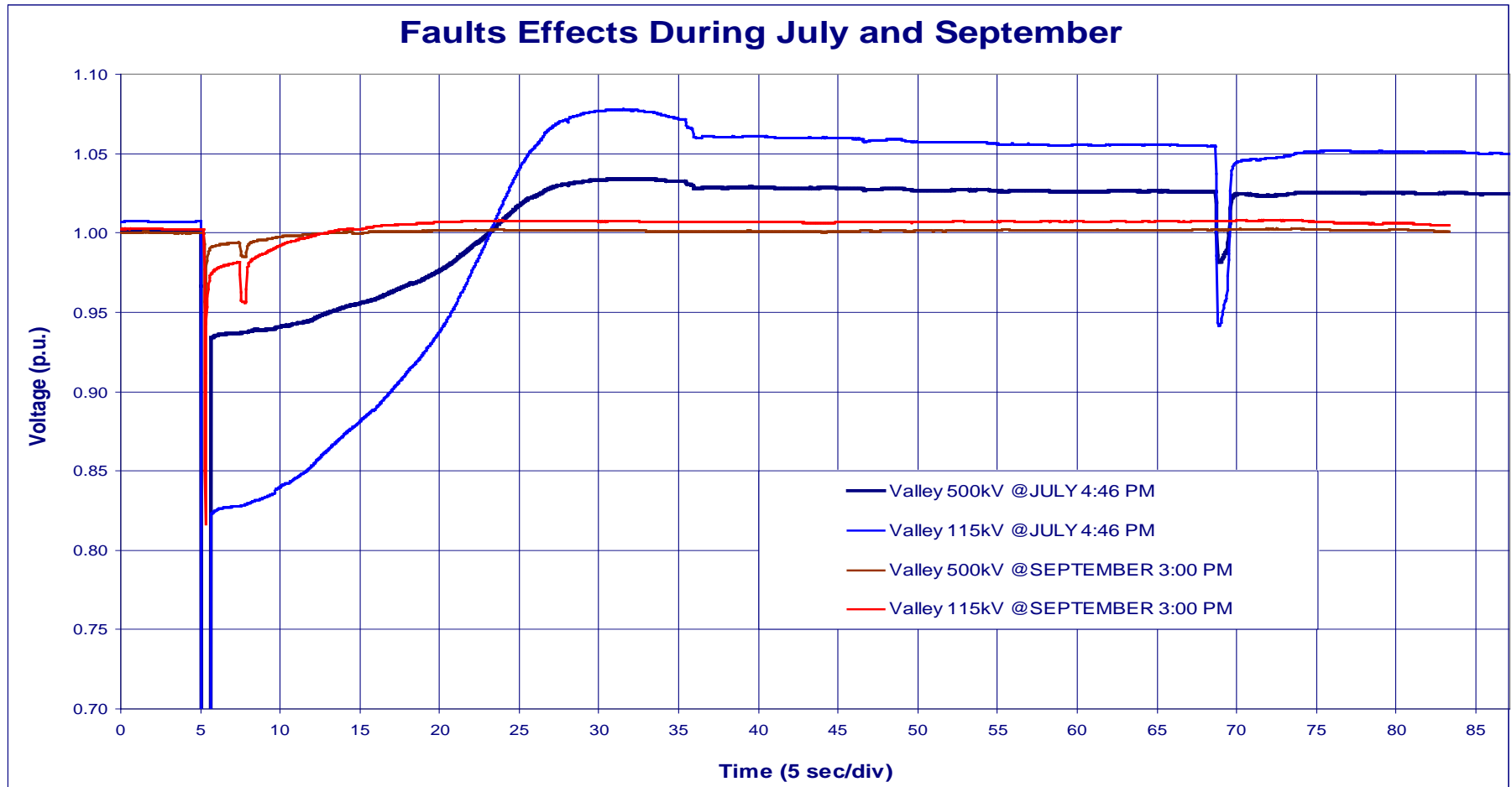
DOE/NERC Workshop

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Fault Effects in the Grid

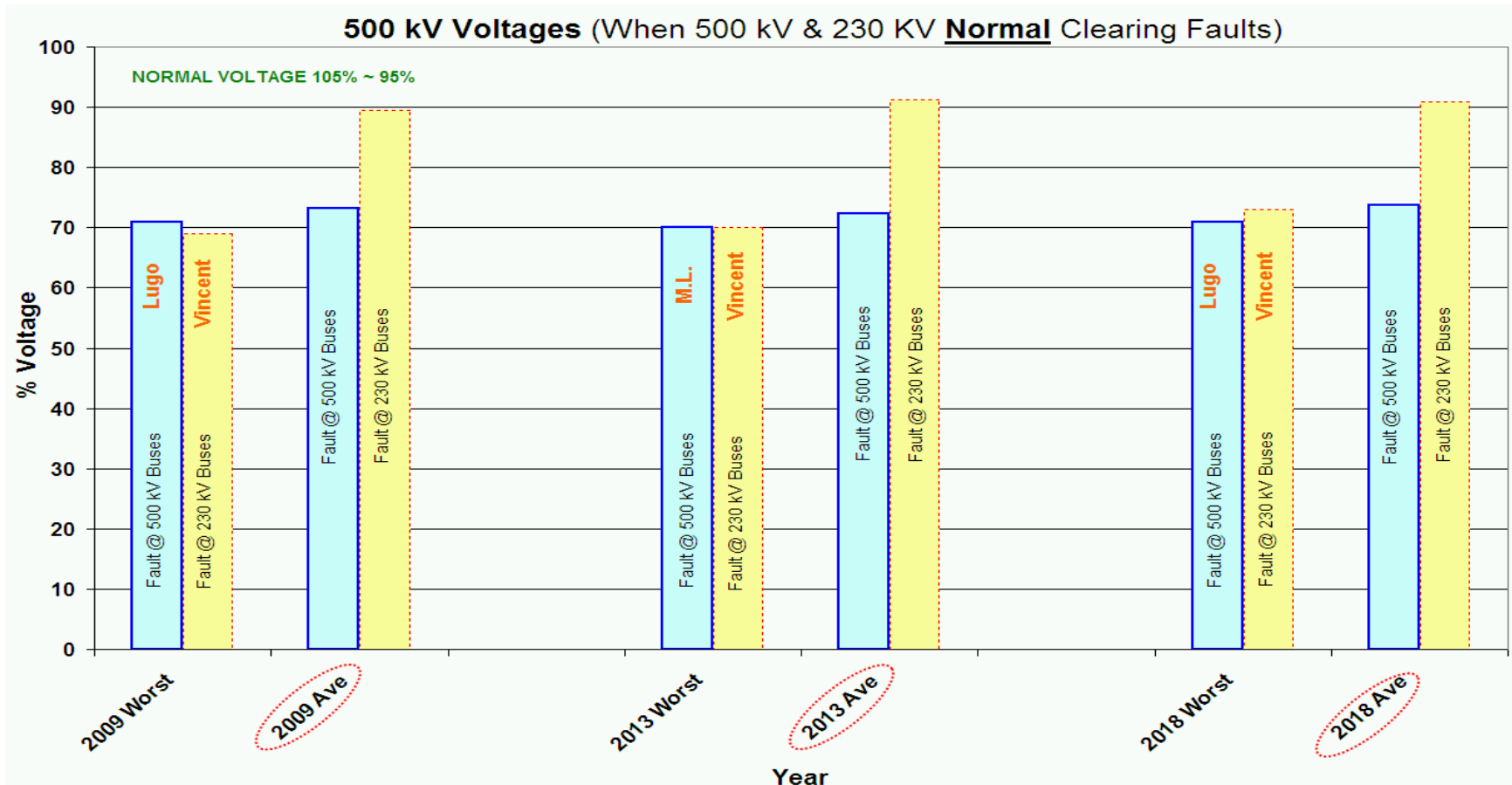
- Two separate events in the same year; high and low A/C load



Voltage Collapse Study

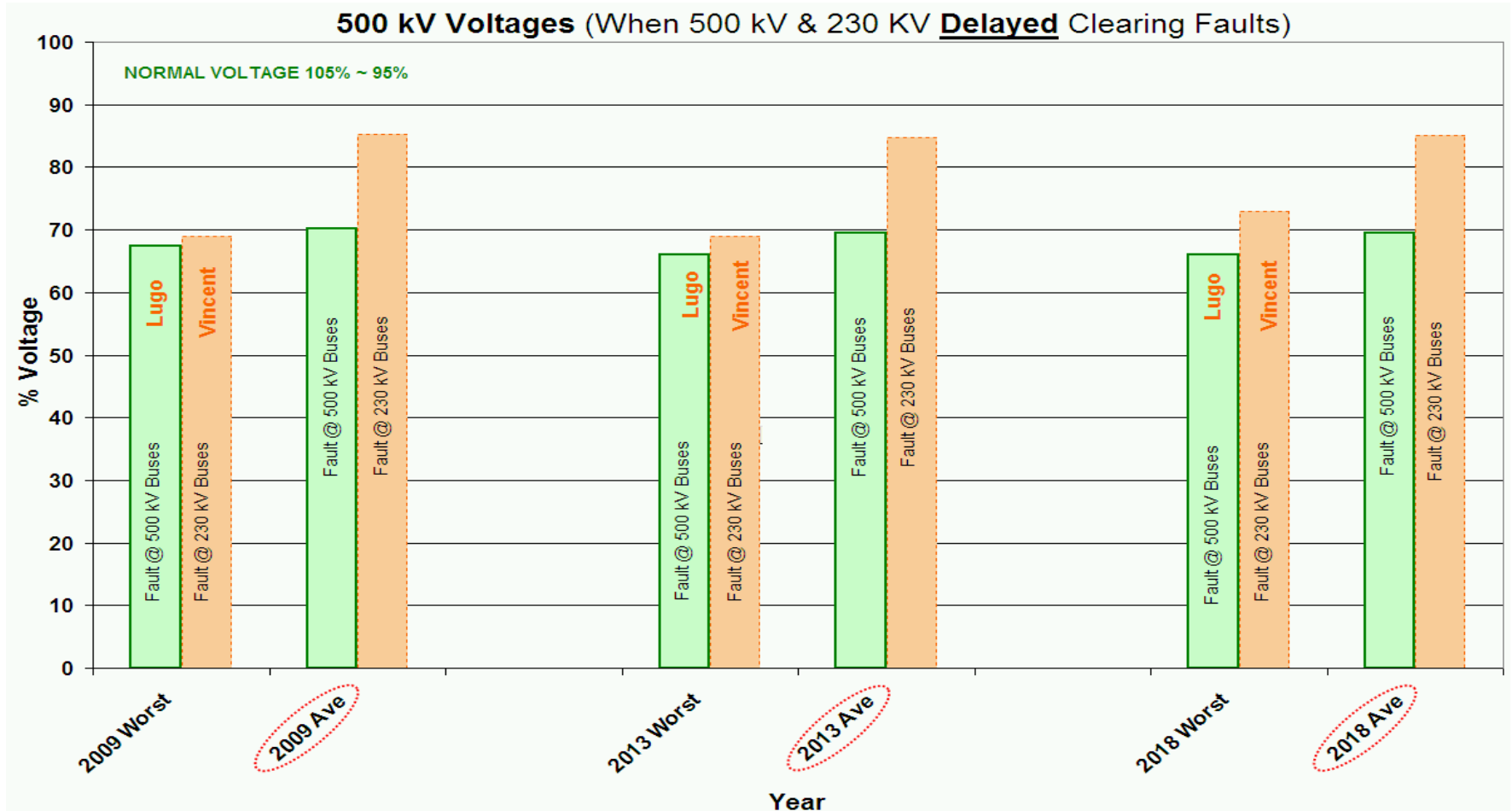
500 kV Voltage Deviation Normal Clearing

- Worst 500 kV voltages after fault clearance are similar for faults in the 500 kV and 230 kV
- Average 500 kV voltages due to 230 kV faults are much higher because A/C stalling is localized



500 kV Voltage Deviation Delayed Clearing

- Voltages are consistent for all modeled years
- Voltages are slightly lower than the normal clearing fault simulation results (2%~4%)



Voltage Collapse Study Observations

- No voltage collapse has been observed
- Still need further study of generator behavior
- Performed studies using PSCad and PSLF
 - Study results are consistent

A/C Stalling Solutions

A/C unit level solutions --- undervoltage relays (UVR)



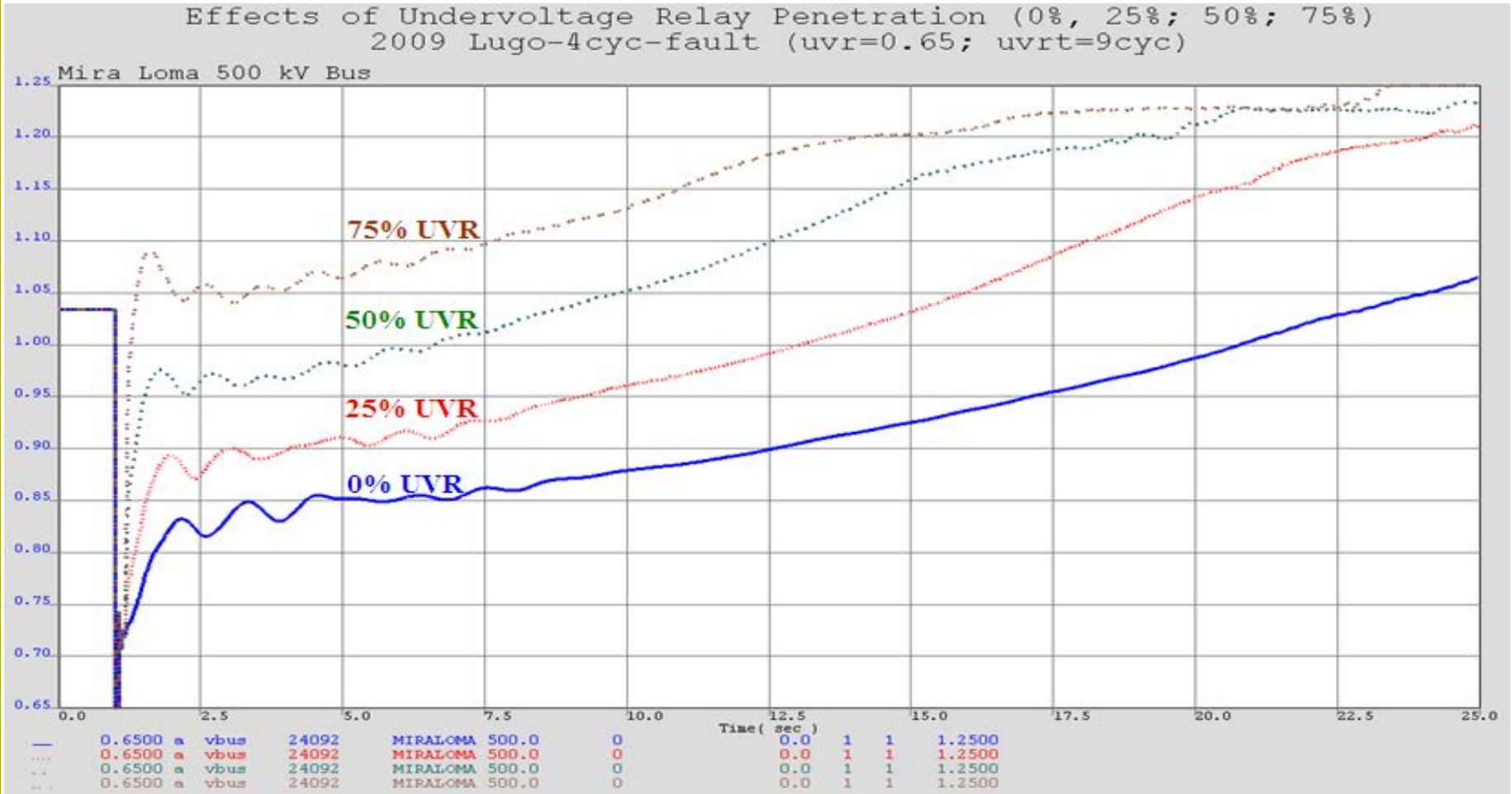
System level solutions --- Static VAR Compensator (SVC)



Undervoltage Relay (UVR) Effects

UVR Effects

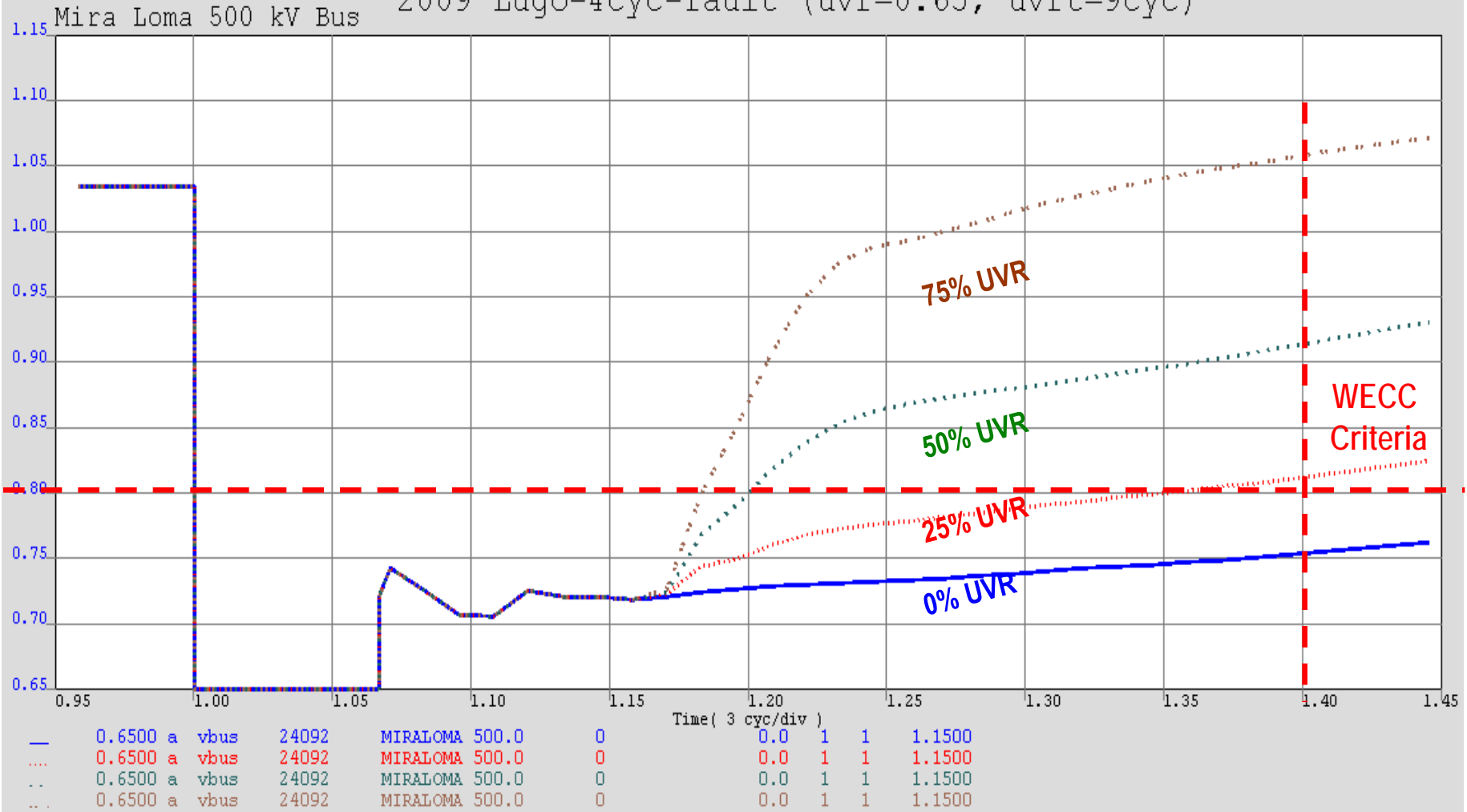
- UVR undervoltage threshold 65%
- UVR time delay 9 cycles



Zoom-in 30 Cycles Results

Effects of Undervoltage Relay Penetration (0%; 25%; 50%; 75%)

2009 Lugo-4cyc-fault (uvr=0.65; uvrt=9cyc)



UVR Observations

- 25% UVR penetration barely complies with WECC criteria
 - WECC criteria 80% within 20 cycles after fault clearance
- 85% and 65% UVR undervoltage threshold did not make significant difference in recovery time
 - 65% gives less false trips
- 15-20 cycles tripping delay should pass WECC criteria
- No difference in overvoltage magnitude if A/Cs are removed by thermal protection or UVR
 - The time of the overvoltage occurs later when relying on thermal protection

Static VAR Compensator (SVC) Effects

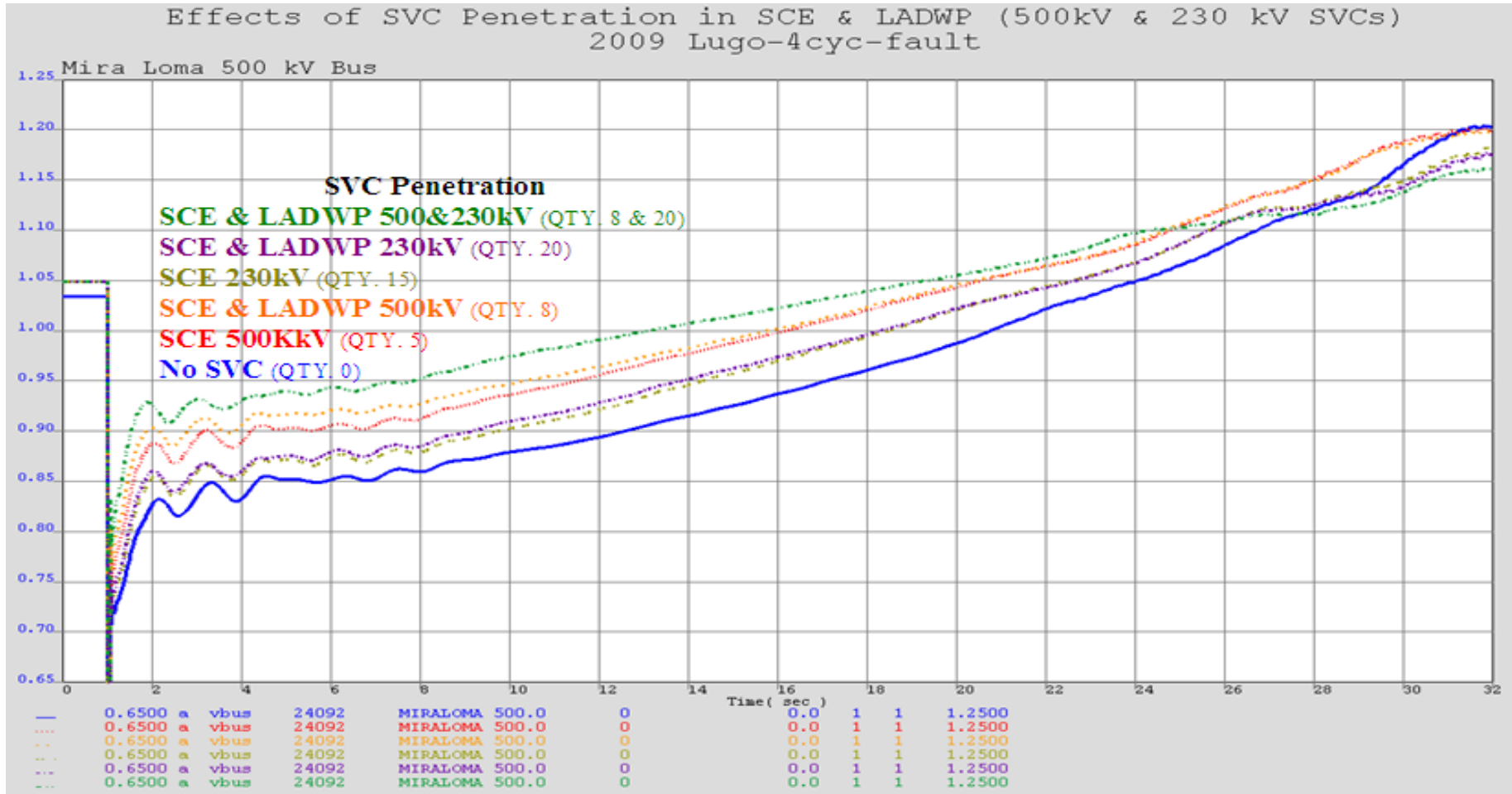
SVC Penetration

- Install several SVCs across SCE and LADWP base-case (500kV, 230kV, and 115 kV) with same parameters as Devers and Rector

Substation	As SCE Devers & Rector		Same C&L	
	MVAR (-)	MVAR (+)	MVAR (-)	MVAR (+)
SCE 500	-550 (ea)	110 (ea)	-550 (ea)	550 (ea)
SCE 230/115	-200 (ea)	120 (ea)	-200 (ea)	200 (ea)
LADWP 500	-550 (ea)	110 (ea)	-550 (ea)	550 (ea)
LADWP 230	-200 (ea)	120 (ea)	-200 (ea)	200 (ea)
Total	-8400	3280	-8400	8400

SVC Effects

- 500 kV SVCs inductive component 20% of capacitive component
- 230/115 kV SVCs inductive component 60% of capacitive component
- Capacitive = +8400 MVAR; Inductive = -3280 MVAR

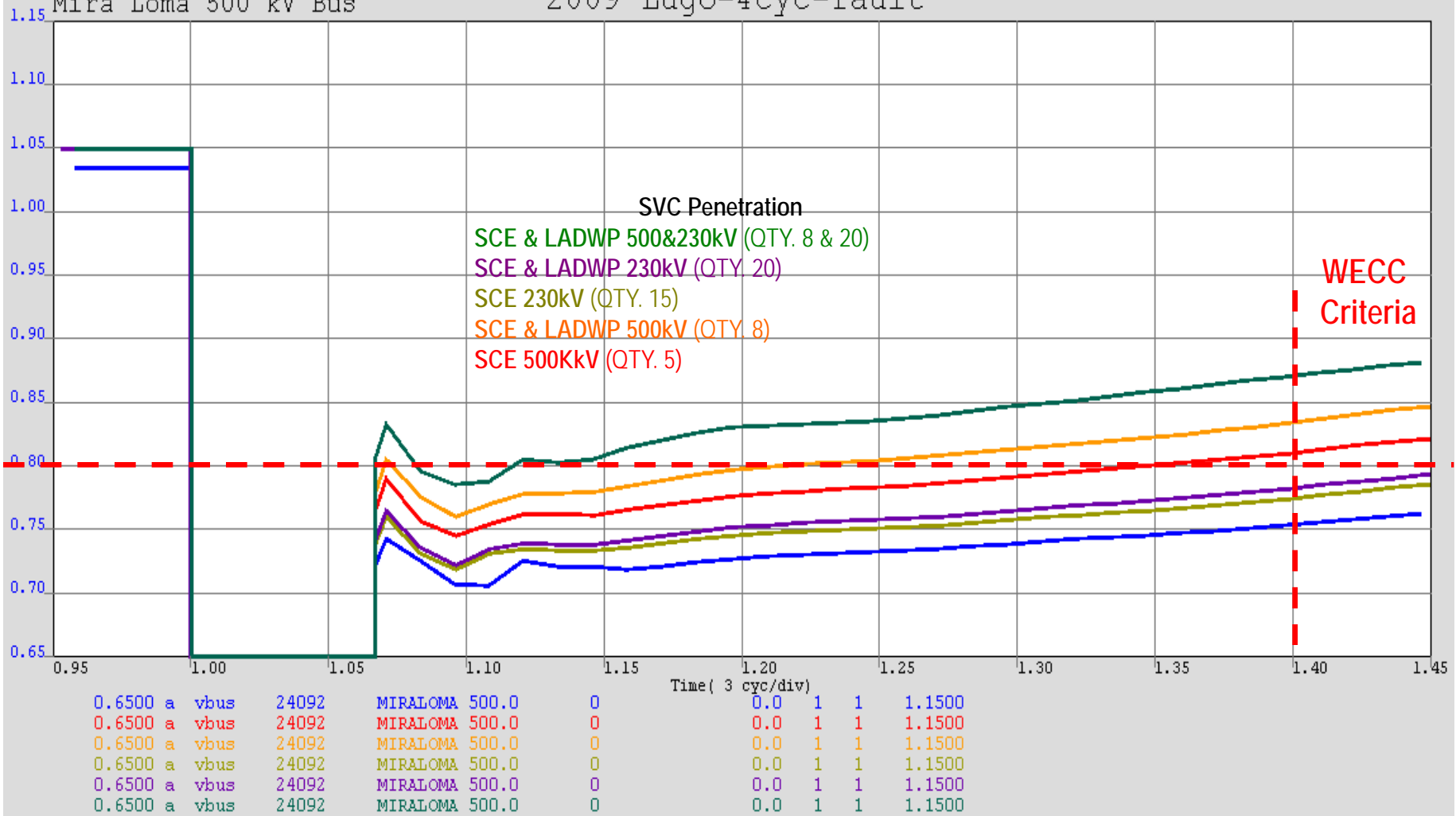


Zoom-in 30 Cycles Results

Effects of SVC Penetration in SCE & LADWP (500kV & 230 kV SVCs)

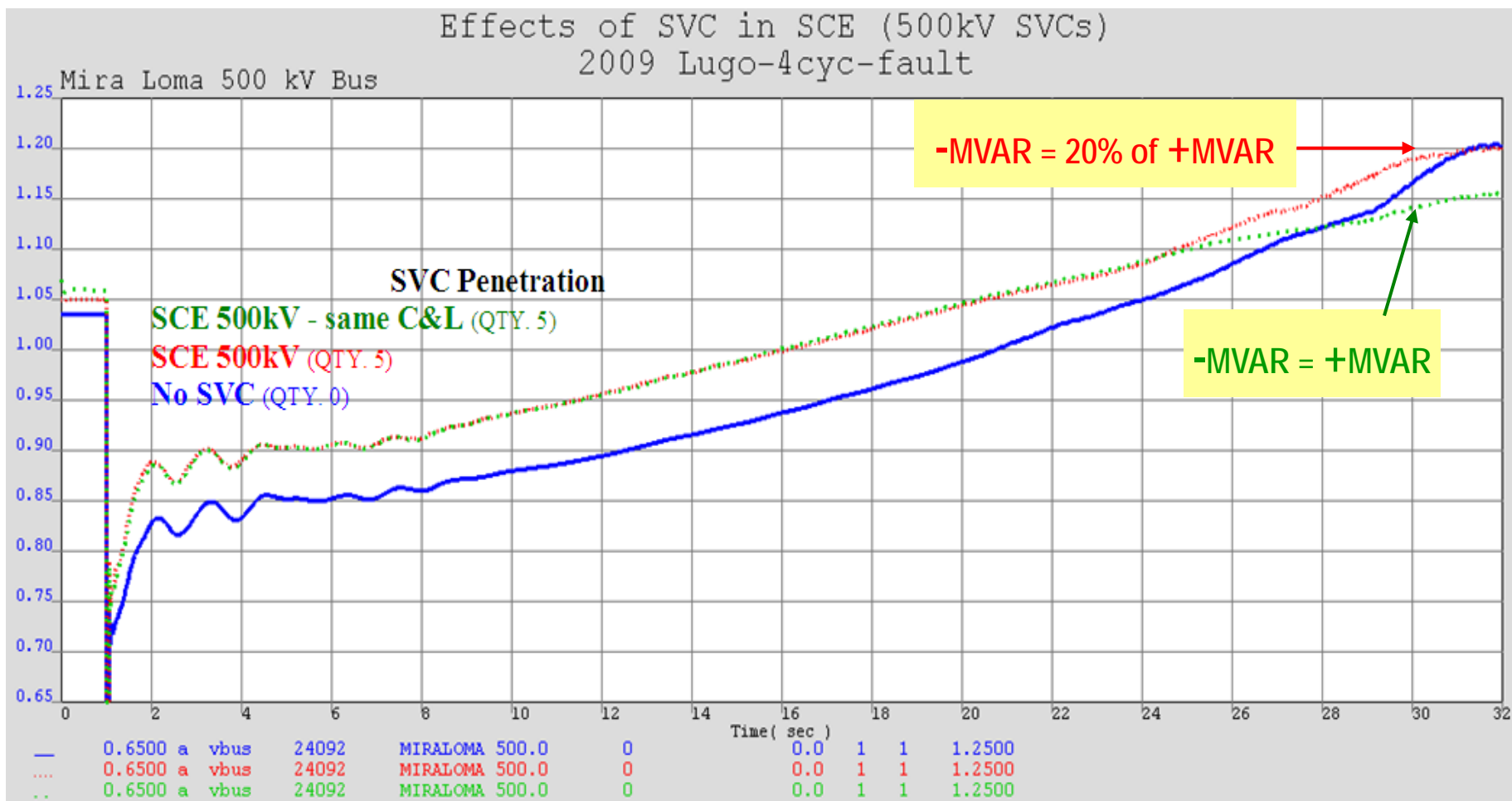
Mira Loma 500 kV Bus

2009 Lugo-4cyc-fault



SVC Inductive Rating Effects

- Comparing equal and 20% SVC inductive and capacitive components
 - Equal --- Capacitive = +2750 MVAR; Inductive = -2750 MVAR
 - 20% --- Capacitive = +2750 MVAR; Inductive = -550 MVAR



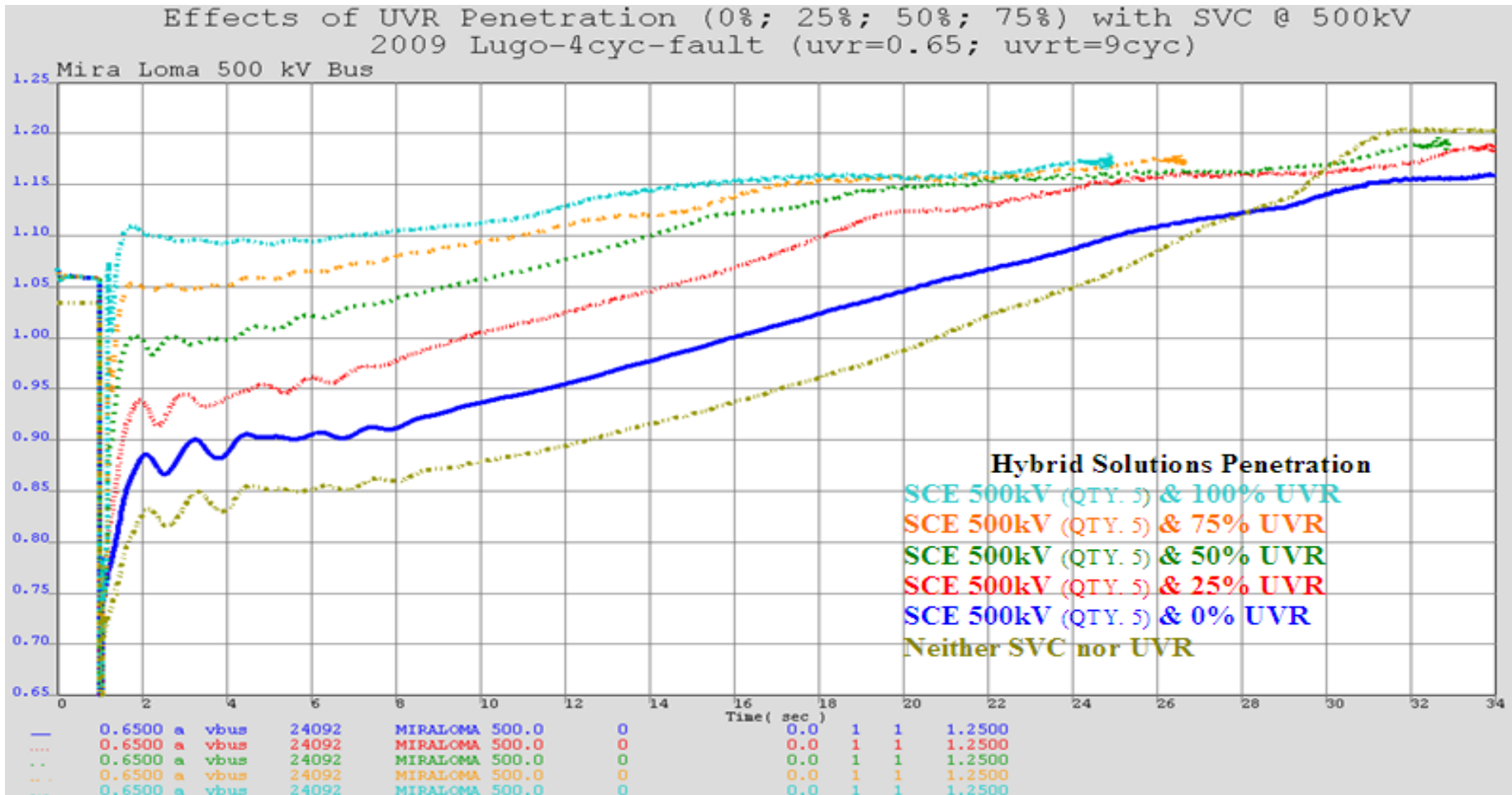
SVC Observations

- Faults are 500 kV transmission
 - 230/115 kV faults are more localized
- Overall SVCs connected at higher voltage (500 kV) perform better
 - Shortens recovery time
- SVCs with higher inductive component reduce overvoltage
- SVCs do not prevent the A/C stalling, help contain it
- Even with large SVC penetration FIDVR events occurs

UVR & SVC Effects

UVR and SVC Effects

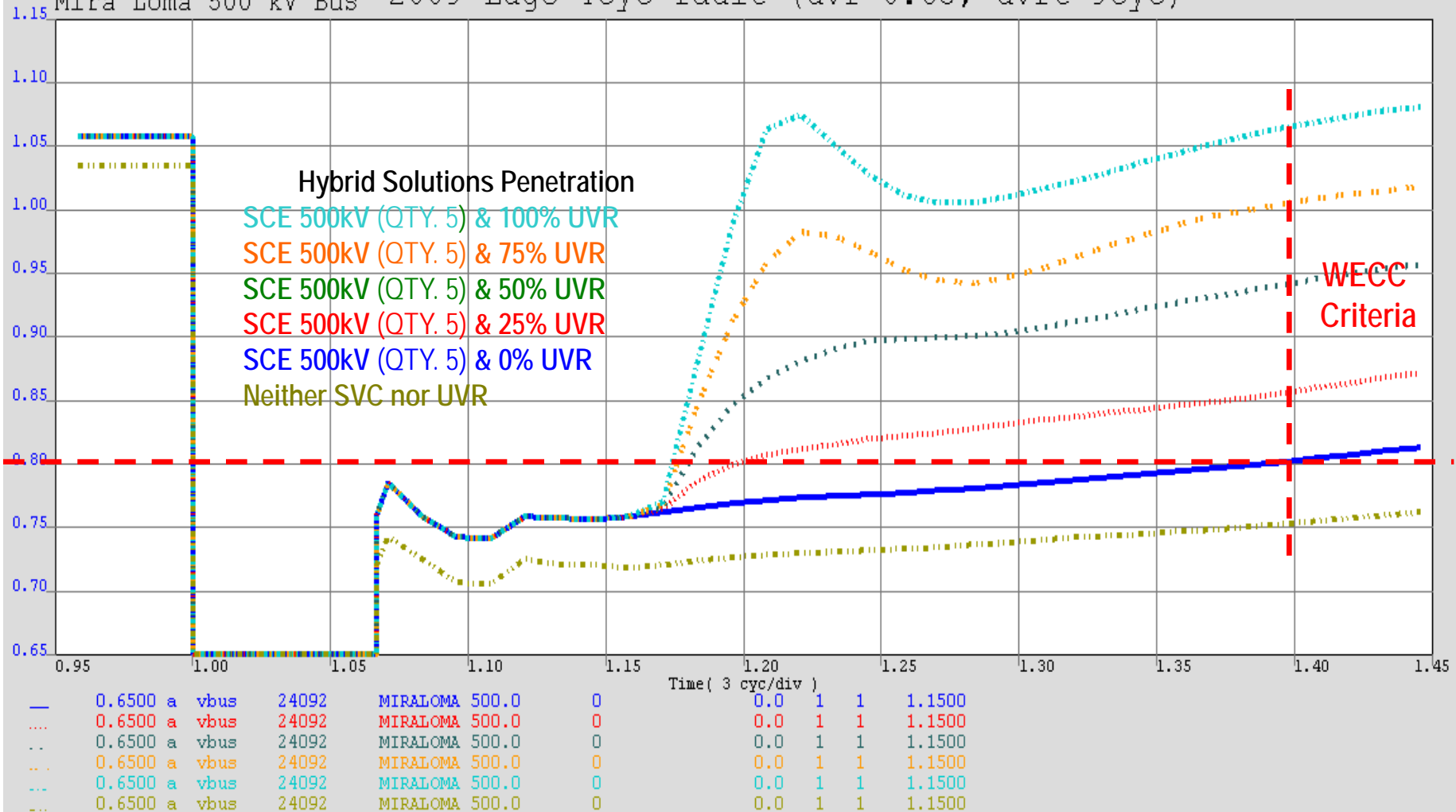
- UVR undervoltage threshold 65%; UVR time delay 9 cycles
- Five SVC at SCE 500kV (550 ±MVAR each)



Zoom-in 30 Cycles Results

Effects of UVR Penetration (0%; 25%; 50%; 75%) with SVC @ 500kV

Mira Loma 500 kV Bus 2009 Lugo-4cyc-fault (uvr=0.65; uvrt=9cyc)



UVR & SVC Observations

- UVR make the voltage recover faster after the fault
- SVC help limit overvoltage when high penetration of UVRs
- 75% UVR penetration or higher creates instantaneous overvoltages
- The best approach to solve the FIDVR events is to implement a hybrid solutions with UVR and SVC
- Tripping only stalled A/C will prevent high overvoltages
 - Tripping less A/C units helps stabilize voltage after the FIRVR event

Conclusions

- No fast voltage collapse has been observed
- UVR have greater impact than SVC on FIDVR events
 - Magnitude and duration
- Unnecessary tripping of running A/C units contributes to higher overvoltages
- Ideal unit level solution would only trip stalled A/C units
- SVCs help but do not prevent A/C units from stalling.
 - They will help contain the problem and lower the overvoltage
- SVC are recommended to have same inductive and capacitive ratings to help stabilize overvoltages

What is Next?

- Revise studies with new WECC SVC model
- Review generator behavior during FIDVR events
 - Out-of-step issues
 - Issues that might trip off generators
- Propose stall protection relay parameters to AHRI
- Propose solutions to overvoltage problems

Thank You

Questions?

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