NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

EV Chargers

Draft findings of Grid Impact

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WECC MVS
May 25, 2023

RELIABILITY | RESILIENCE | SECURITY




Background

- This work builds off past LMWG presentations by Joe Eto
- DOE, NERC, GE, and EPRI coordination in for beta model

DOE Transmission Reliability R&D Program

Distribution-Level Impacts of Plug-in Electric Vehicle Charging on the Transmission System during Fault Conditions

NERC Load Modeling Working Group
October 28, 2021

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Pacific Northwest NATIONAL LABORATORY

PNNL-31558

Distribution-Level Impacts of Plug-in Electric Vehicle Charging on the Transmission System during Fault Conditions

October 2021

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Background

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Electric Vehicle Dynamic Charging Performance Characteristics during Bulk Power System Disturbances

Synopsis

The purpose of this document is to highlight the need for collaboration between electric utilities and the electric vehicle (EV)/electric vehicle supply equipment (EVSE) manufacturing industry to develop strategies that will help ensure bulk power system (BPS) reliability, resilience, and security.[1] This document focuses on an area that is relatively unexplored: EV charging behavior during infrequent grid disturbances that originate from the BPS. These events last no more than a few seconds but may have catastrophic consequences for grid reliability if left unchecked (i.e., cascading blackouts and widespread power interruptions). This document outlines the need for early engagement and information exchange between the electric utilities and the EV/EVSE manufacturing industry to facilitate anticipation and timely resolution of potential grid reliability issues. Toward this end, this document describes the BPS-related reliability concerns that electric utilities are studying in anticipation of the expected significant increase in EV charging loads. This document then outlines the electric utility's current recommendations to mitigate these concerns based on preliminary observations, including changing EV charger and EVSE operation during these infrequent, short-duration events. This document concludes by outlining a solution to meet the need for on-going information sharing between the two communities. This includes the need for future studies to refine these recommendations to become accepted industry practices and standards. This coordination will foster mutual understanding of the issues that must be addressed on both sides of the meter to ensure grid reliability, resilience, and security at the least cost to society as electrification of the transportation fleet grows.

- Recommends steady-state control of Constant I over Constant P
- Droop control of 5%
- Operate in "grid-friendly manner"
  - Continuous Operation
  - Grid Disturbances
  - Severe Grid Conditions (e.g., blackouts)

https://www.nerc.com/comm/RSTC/Documents/Grid_Friendly_EV_Charging_Recommendations.pdf

Grid Friendly and Grid Unfriendly Behavior

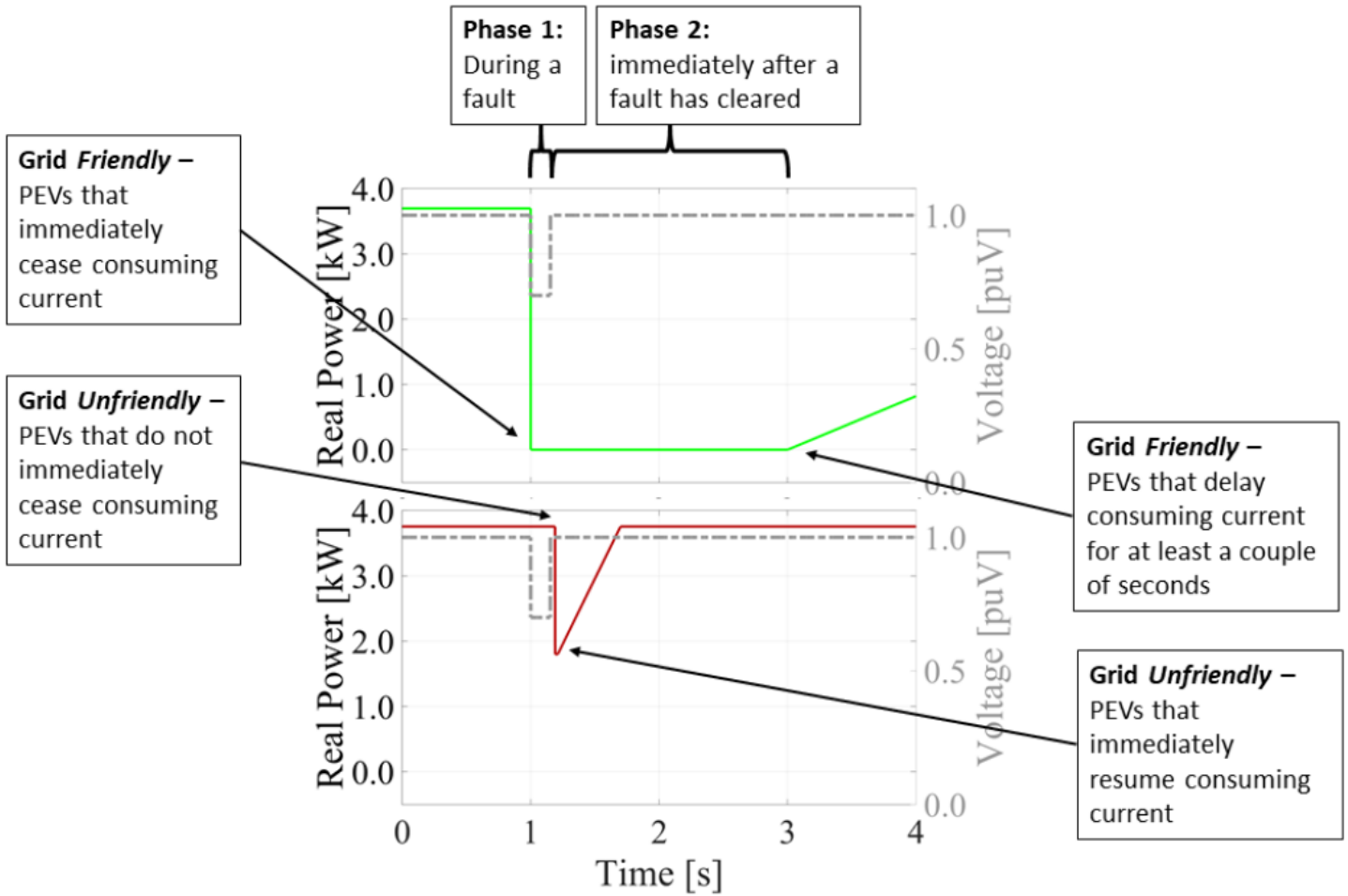


Figure EX-1 – Summary of Grid Friendly and Grid Unfriendly PEV Behaviors

Characterization of EV Response

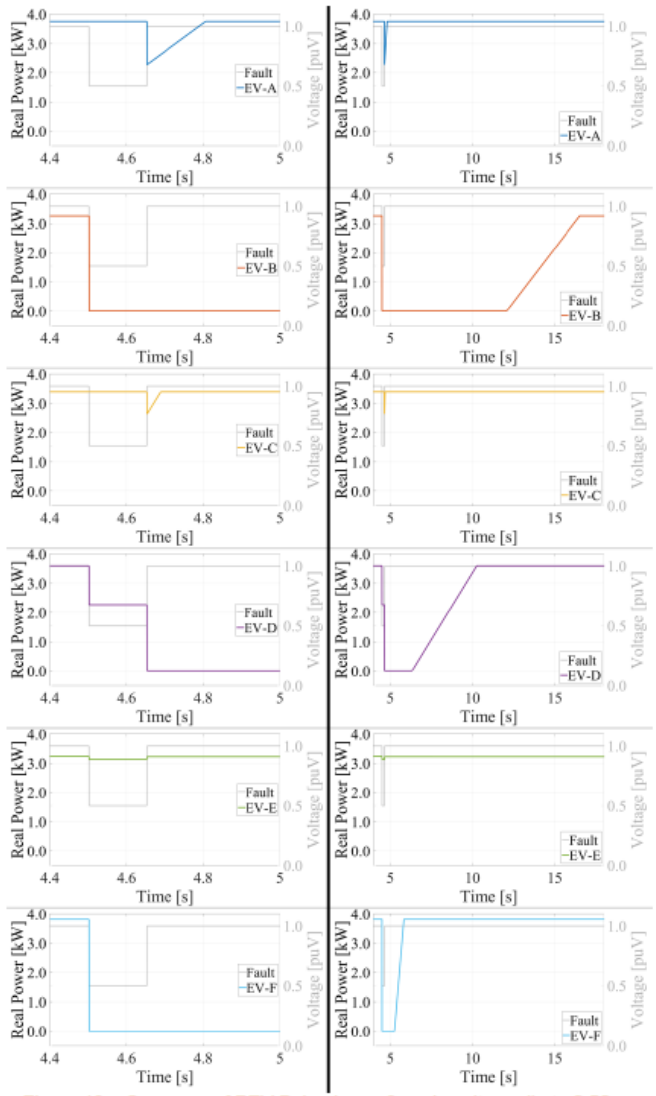
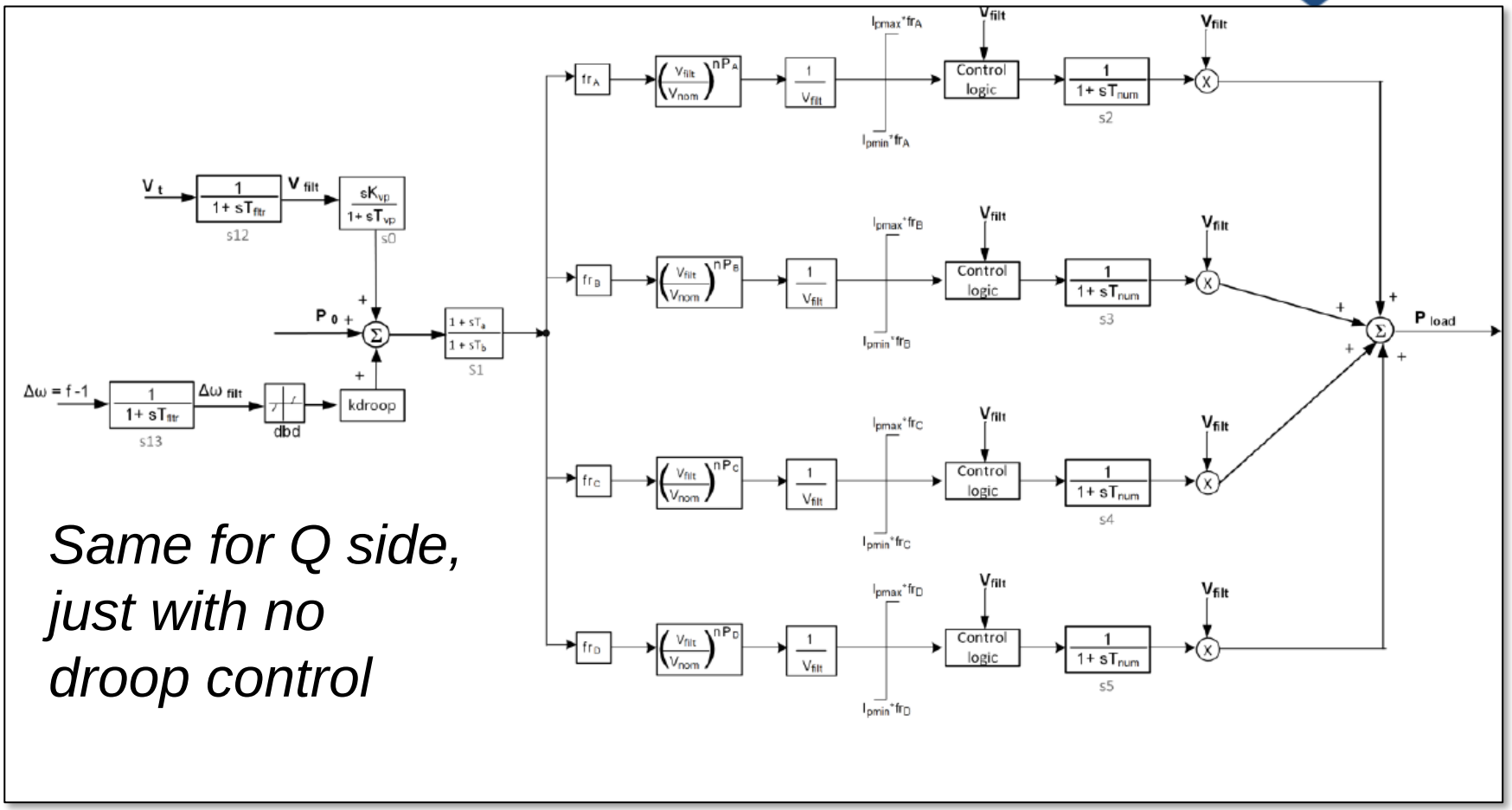


Figure 19 – Summary of PEV Behaviors – 9-cycle voltage dip to 0.50 pu

Of all 6 types of EV chargers, 4 broad behaviors:

1) Trip for long period of time and recover slow
2) Trip for short period of time and recover quickly
3) Ride-through fault, trip post-fault, and recovery slowly
4) Ride-through fault with minor disruption

4 Broad Behavior Implemented in Beta EV Model

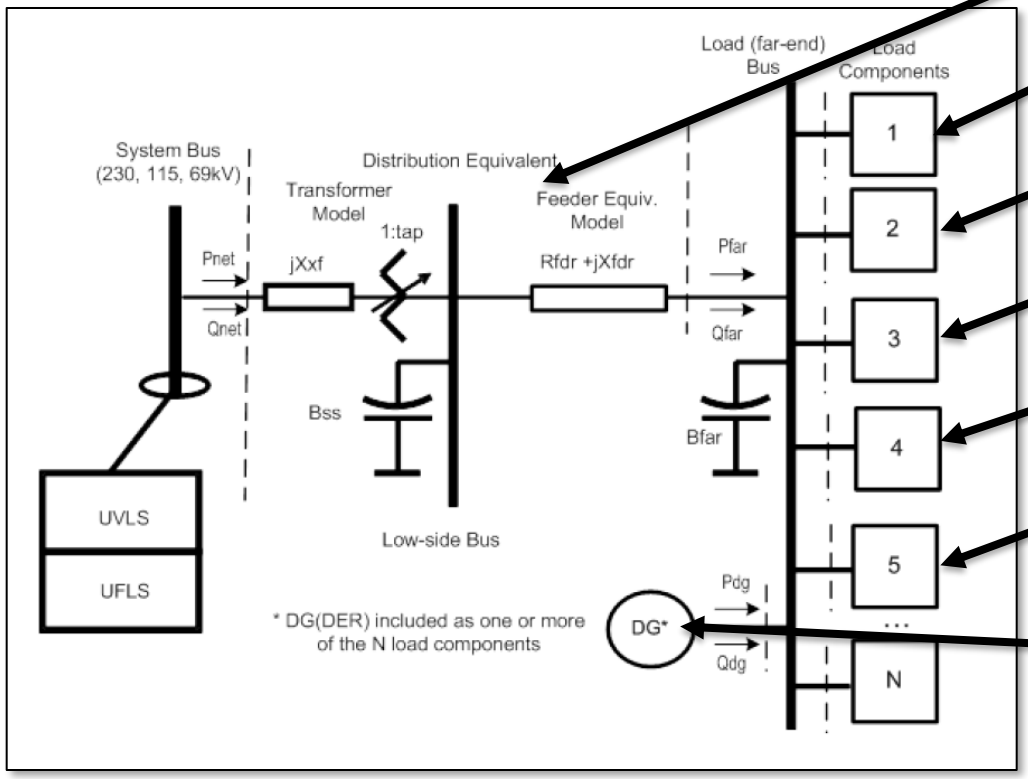


Same for Q side, just with no droop control

Taken from Beta GE software implementation. Subject to change

Component Load Model

- Area-by-Area Data maintainer models for load components, *_cmpldw2*



_cmp_dist

_cmp_1pac

_cmp_mot3

_cmp_elec

_cmp_stat

_cmp_ev1

_cmp_der_a

NERC Study work

- Chose two cases to test the model on
  - Heavy Summer – High loading and stressed conditions
  - Light Spring – for lower flows and voltage stability
- Adjusted cases potentially to allow for:
  - Increase of load and generation to require 100 GW of EV penetration
  - Generation composition
  - Area flow changes to account for Area EV composition being different
- Recovery types studied have the following parameters:
  - Constant P
  - Constant I
  - Fast Recovery Long Ramp = ¼ sec delay and 10 second ramp to pre-dist level
  - Fast Recovery Fast Ramp = ¼ sec delay and 1 second ramp to pre-dist level
  - No Delay Fast Ramp = 0 sec delay and 1 second ramp to pre-dist level
  - Long Recovery = 10 sec delay and 10 sec ramp to pre-dist level

NERC Study Work

- Cases had between 10 and 20% EV penetration
  - Other load is broken down via 3 phase motors, 1 phase motors, static load, etc.
- Studied two types of faults
  - Fault one – 10 cycle 3-phase bus fault on 500 kV substation
  - Fault two - 4 cycle 3-phase bus fault on 500kV substation near known FIDVR conditions exist

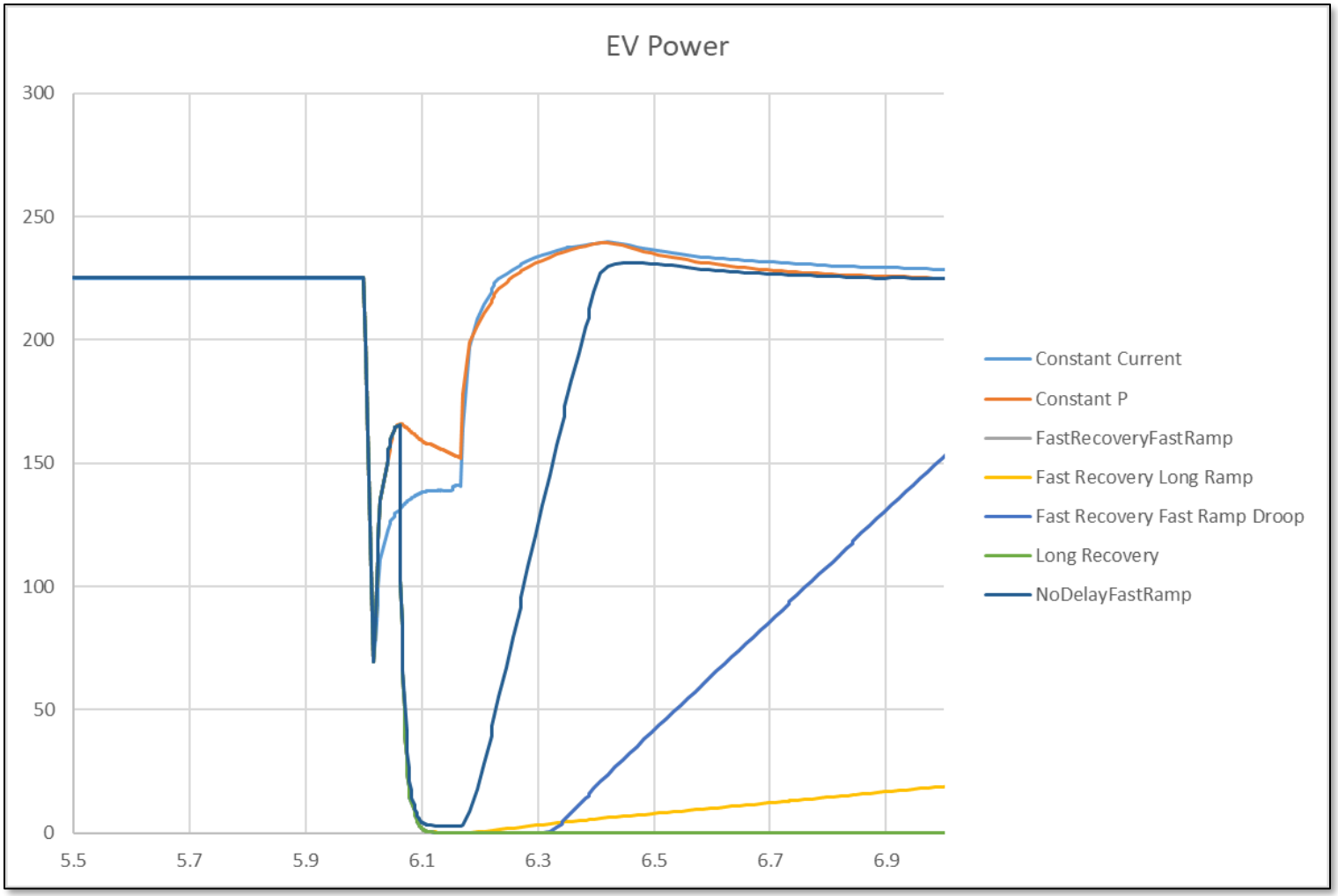
Study Case Comparison				
Case name	**Case Description**	**Total Load**	**Total EV Load**	**EV Percentage of Load**
33HS1a1_EV	NERC modified 2033 Heavy Summer	193,120 MW	37,748 MW	19.55%
24LSP2Sa1_EV	NERC modified 2024 Light Spring	154,775 MW	19,941 MW	12.88%

- Adjusted cases nearing 50% plus EV penetration – In progress

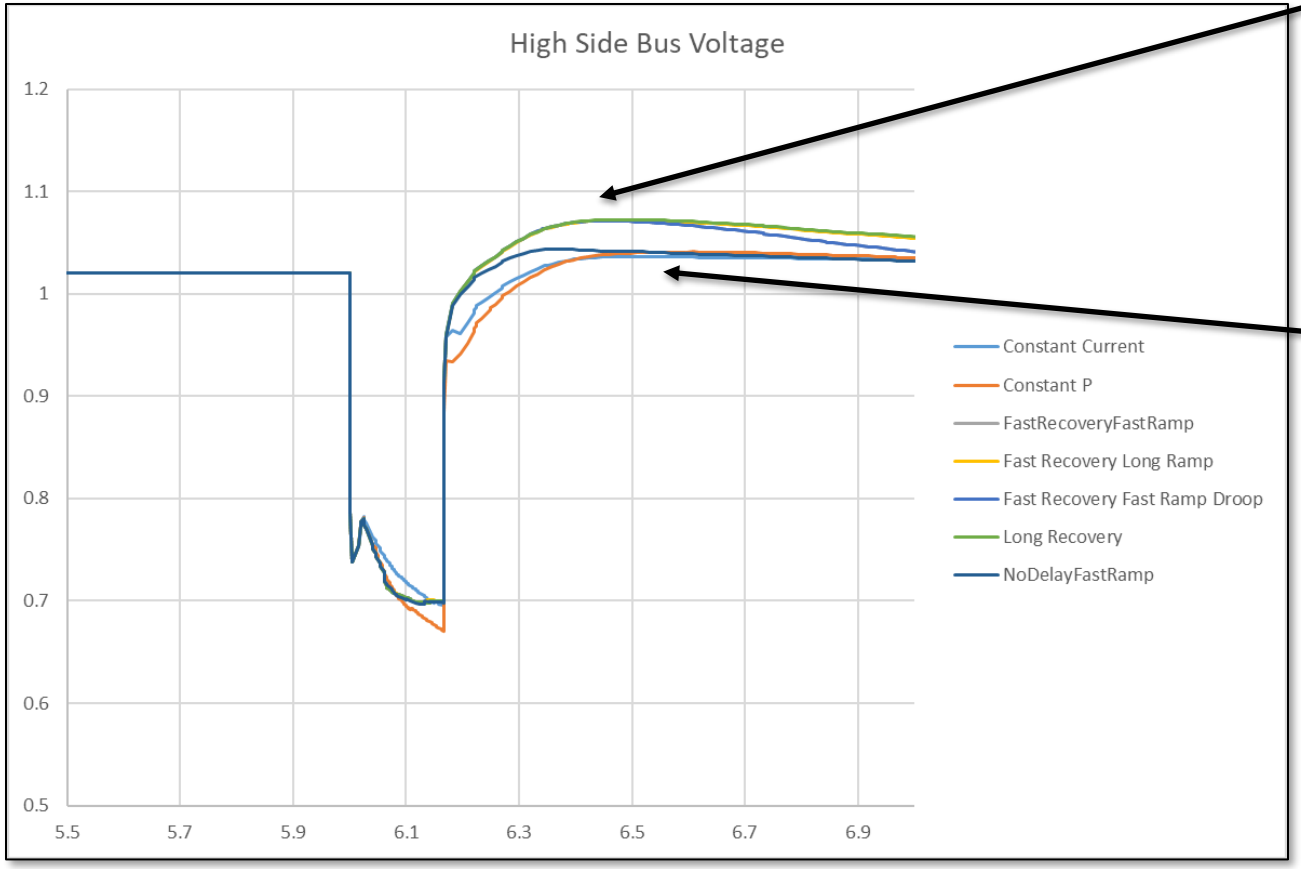
NERC Study Work

- Plots and charts are different for each fault
- Fault one plots and charts show the largest moved EV model to the fault in heavy summer conditions.
  - Interconnection-wide parameters use the aggregate of these responses.
  - Electrically relatively far. (5 buses, 2 transformers)
- Fault two plots the load at the 115 kV yard where the 500 kV bus is applied.
  - Electrically close to the fault (1 bus away through a transformer)

EV Power Recovery – Heavy Summer



High Side Voltage Recovery – Heavy Summer

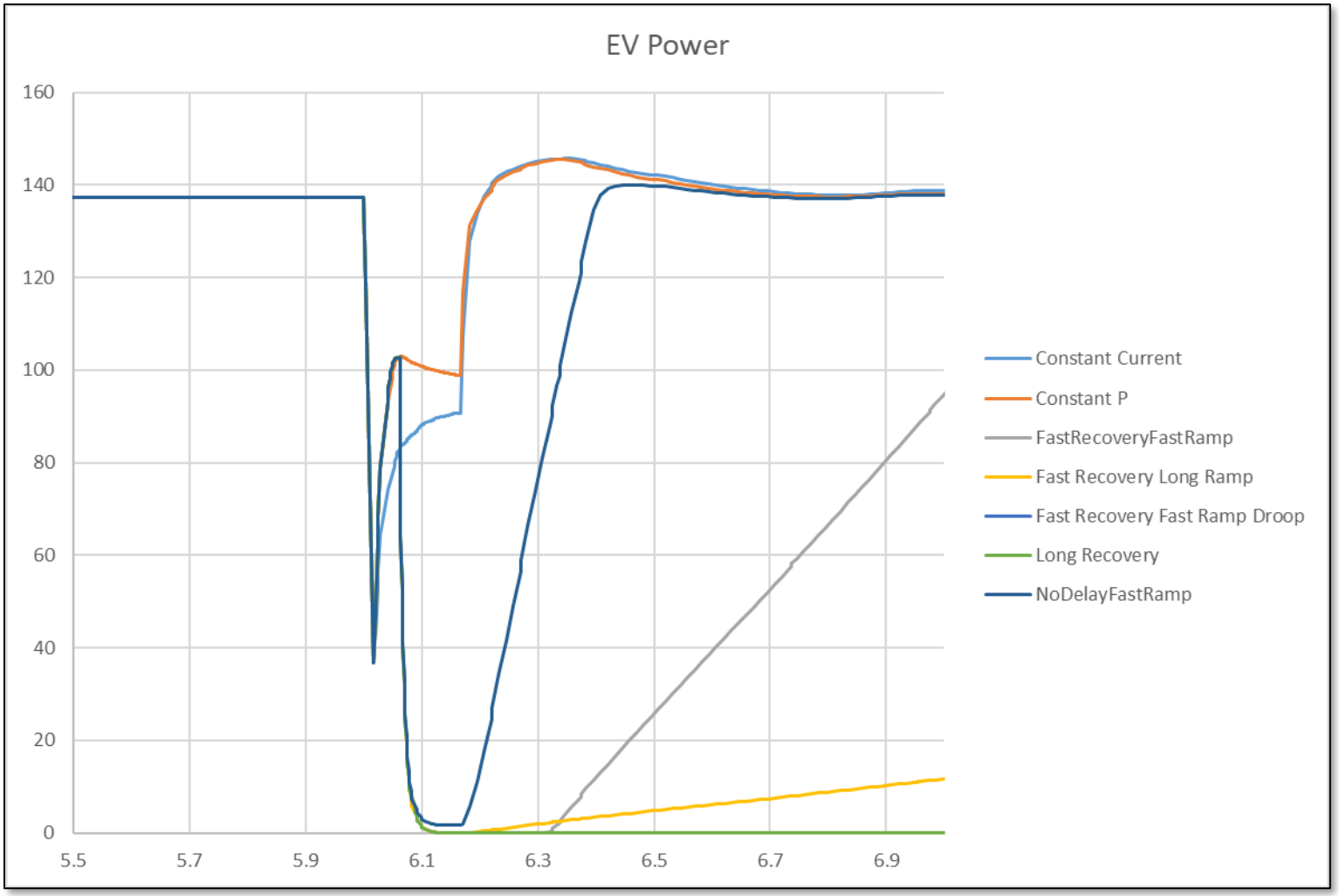


OV condition post-disturbance if slow to recover

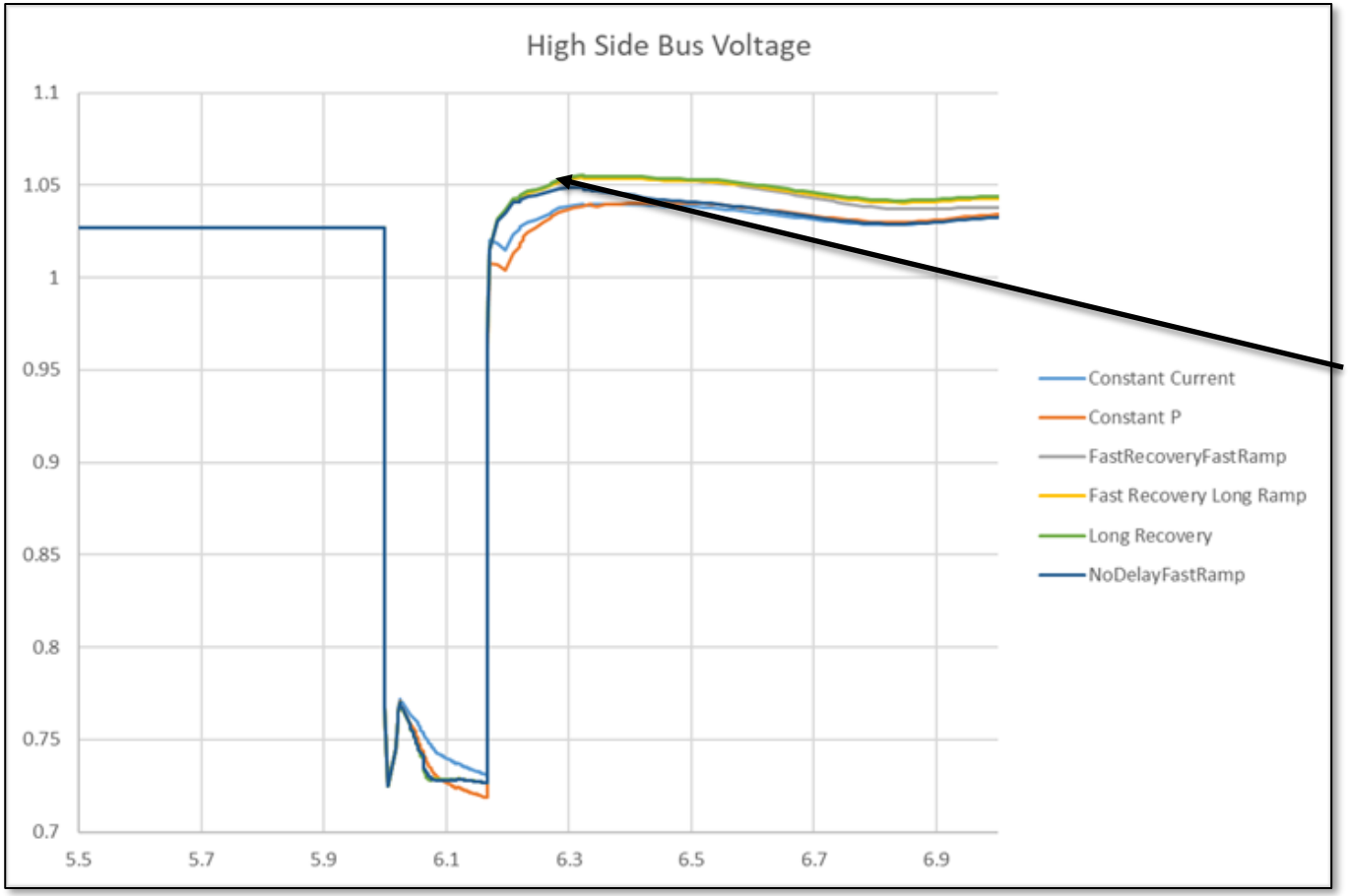
OV condition mitigated with fast recovery and small delays

Ride-through in Const I or Const P preferred!

EV Power Recovery – Light Spring



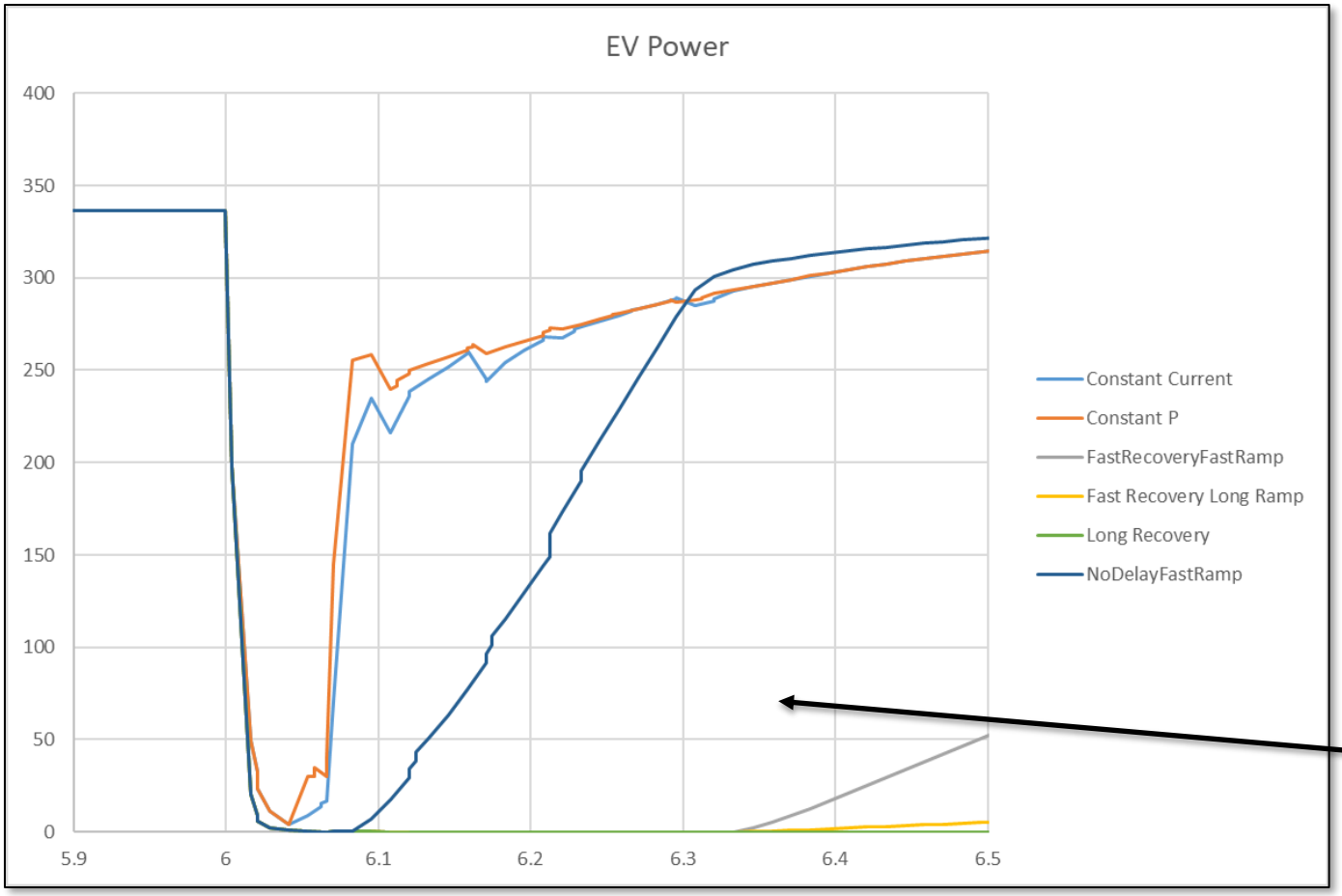
High Side Voltage Recovery – Light Spring



OV condition post-disturbance if ceased, regardless of ramp speed

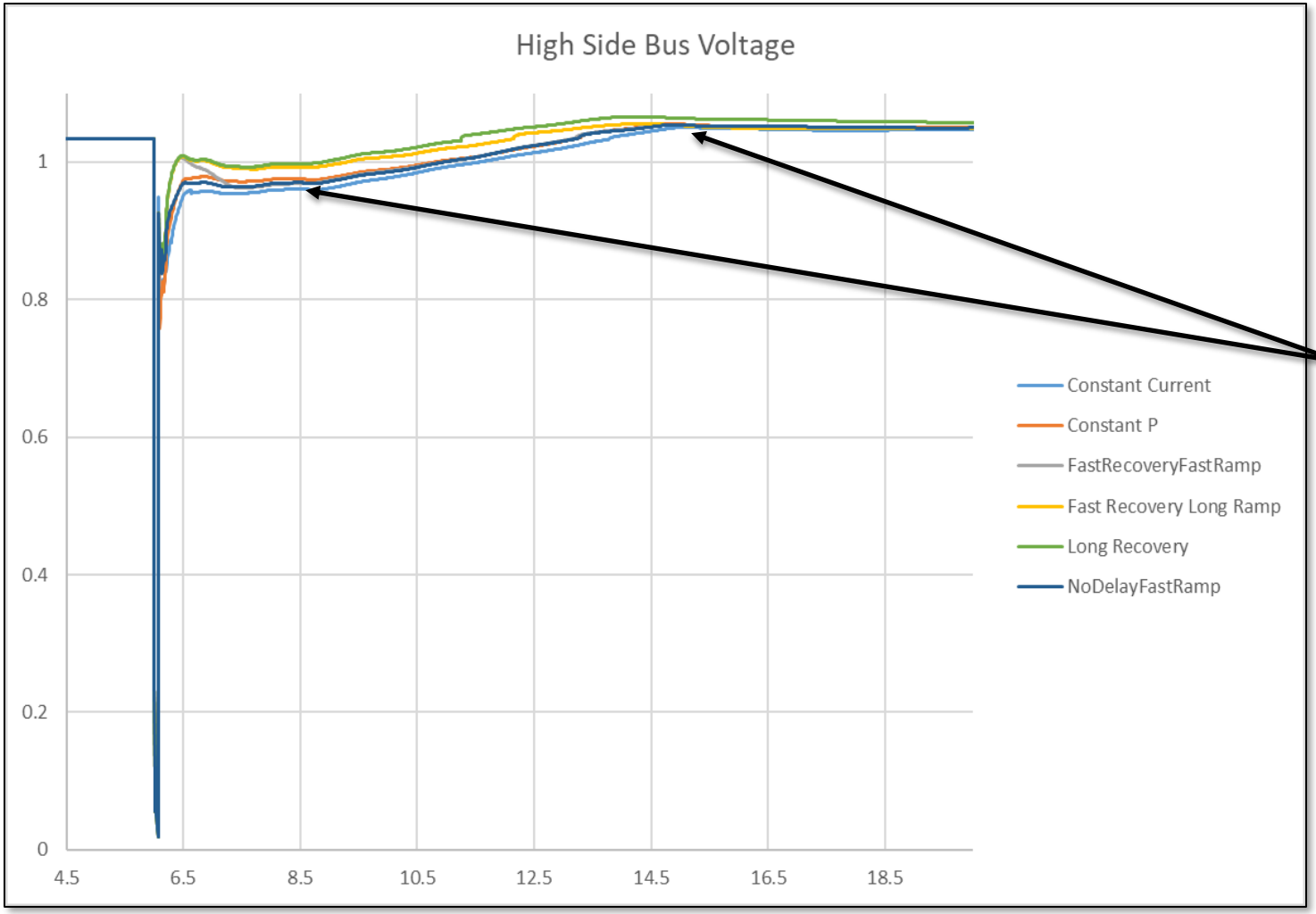
Ride-through in Const I or Const P preferred!

EV Power Recovery – FIDVR Sensitivity



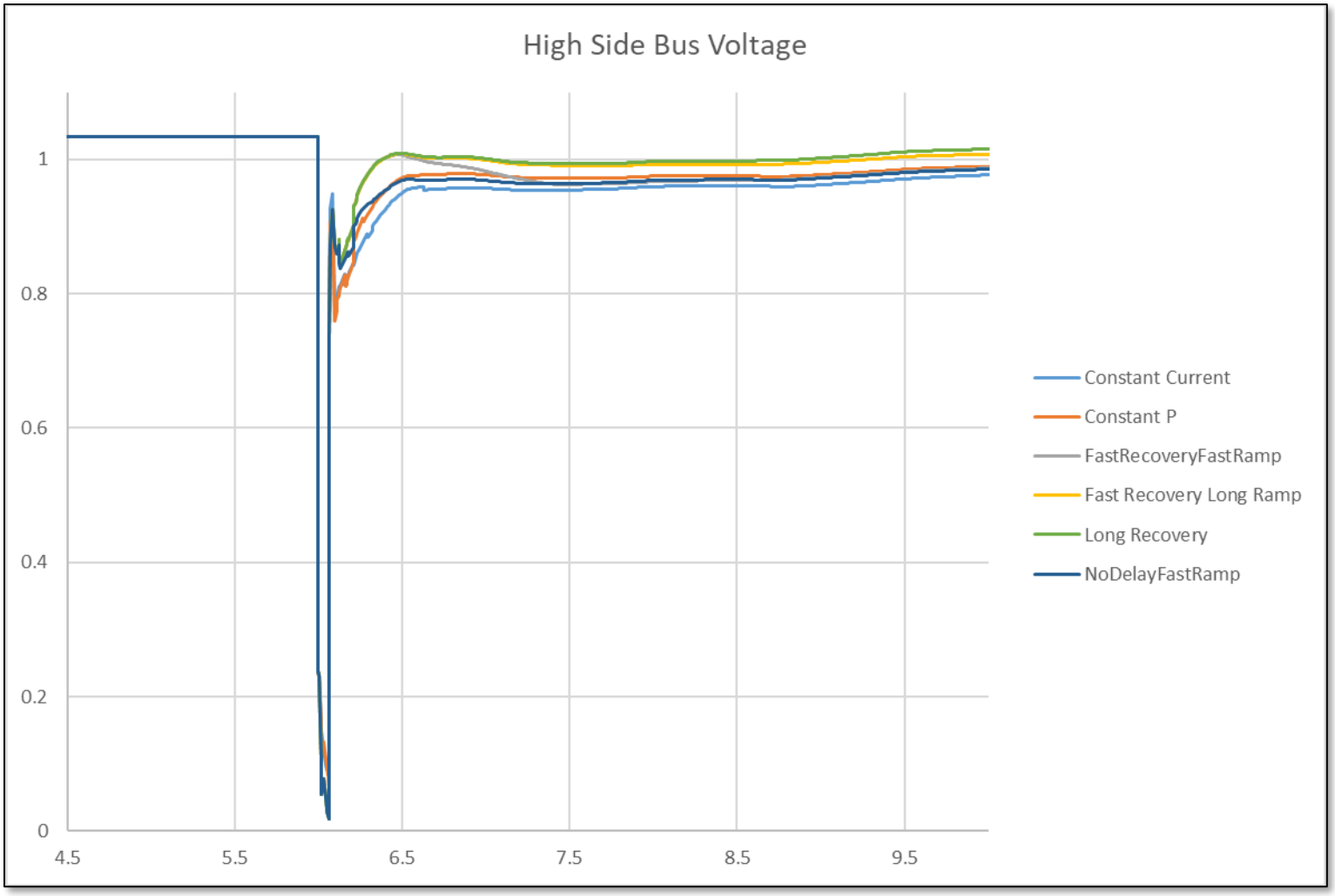
Intentional delays pushed further

High Side Voltage Recovery – FIDVR Conditions



Delay between recovery above 0.95 and new steady state

High Side Voltage Recovery – Zoomed in



*Longer time recovery better**

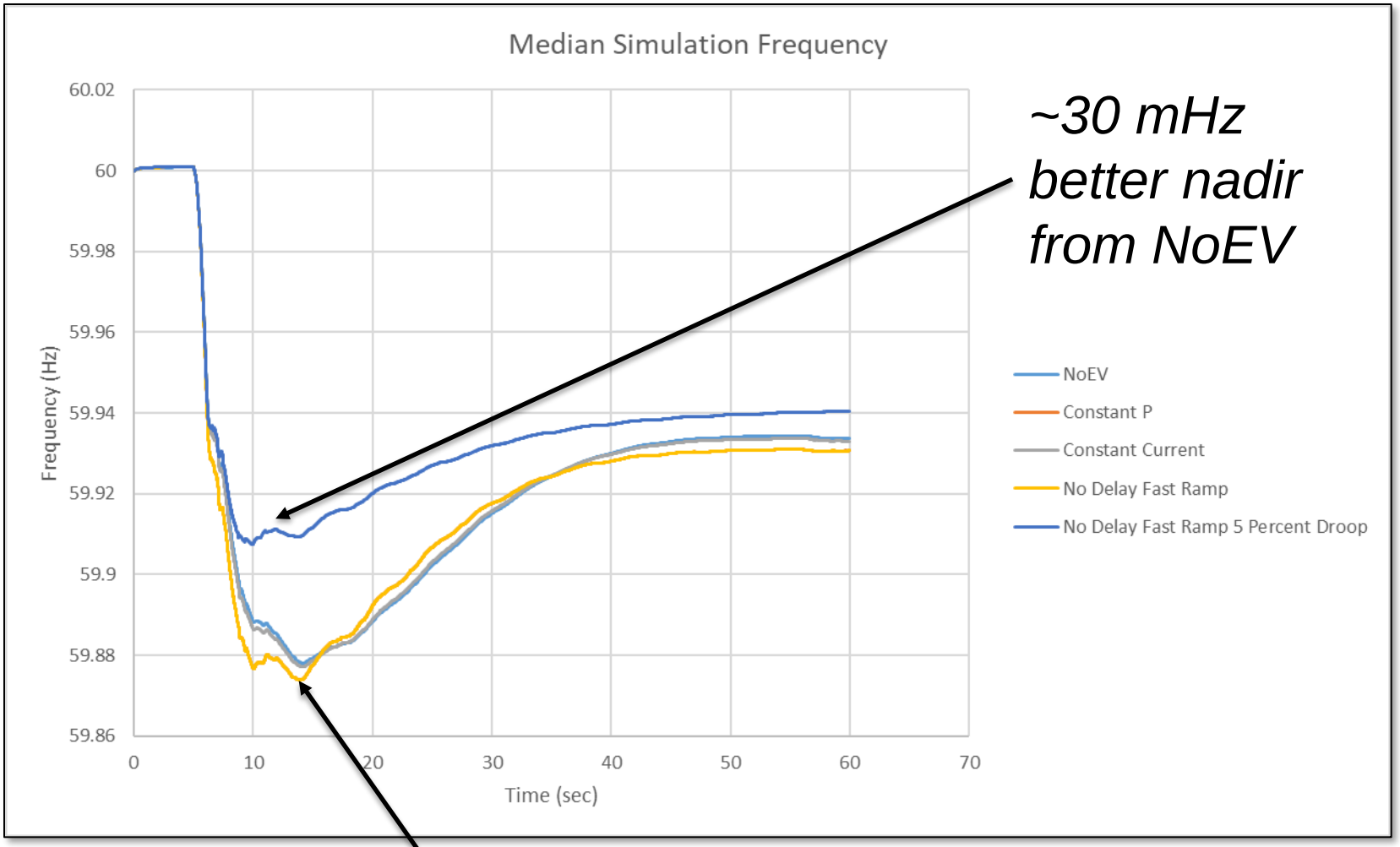
Draft Conclusions and Recommendations

- At a broad level, the implemented aggregate EV model is robust and can represent the aggregate charging equipment
  - Not shown is fractional recovery/cessation capability to have some ride-through in const I and others cease. This is a current capability
- EV charging equipment should either:
  - Ride-through in Constant I or Constant P for fault.
  - Cease charging only when necessary and recover with no intentional time delay and ramp to pre-disturbance set points within 1 second.
  - This confirms the CMC report findings
- FIDVR conditions are not as likely as other grid disturbances, so the longer delays, broadly speaking, aren't grid friendly
  - In areas where FIDVR is still a concern, TPs should require EV chargers to add delay to their recovery.

Resource Loss Testing

- Model assumptions:
  - Outside of all ConsI, modeled load as ConstP with current limits
  - When modeling primary frequency response
    - 5% droop
    - 17mHz deadband

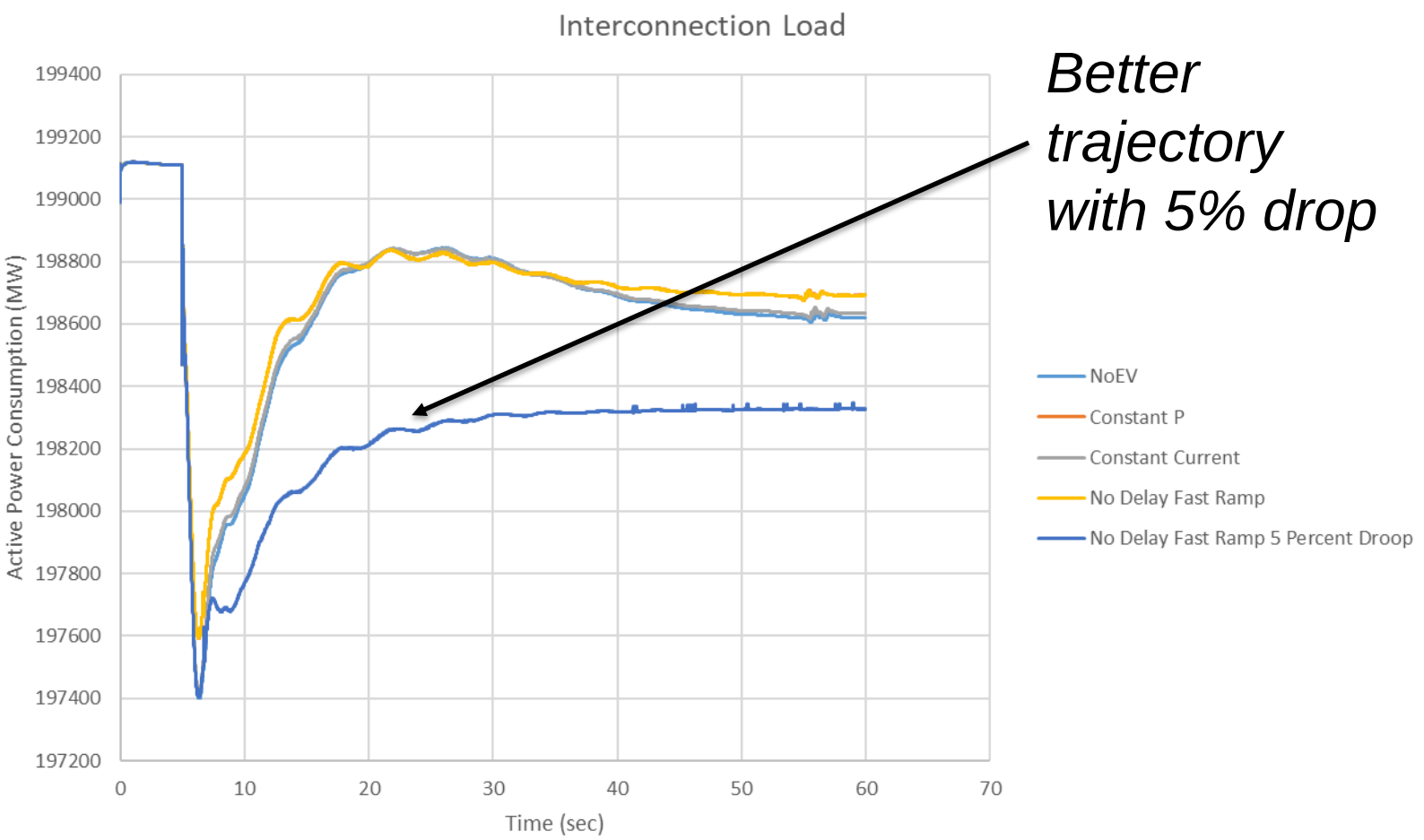
Median frequency



~30 mHz better nadir from NoEV

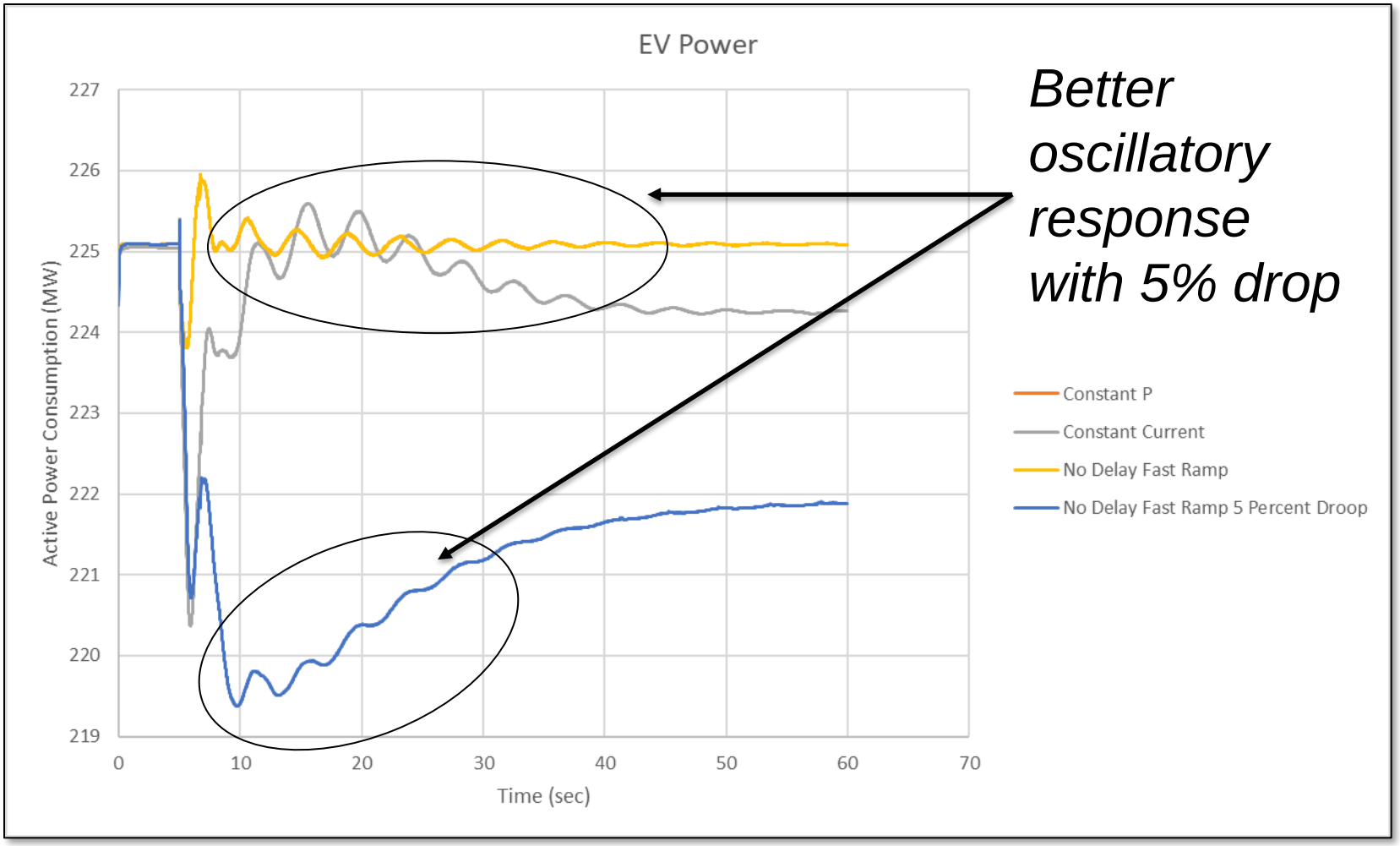
Const P and No Delay overlap

Interconnection-wide load



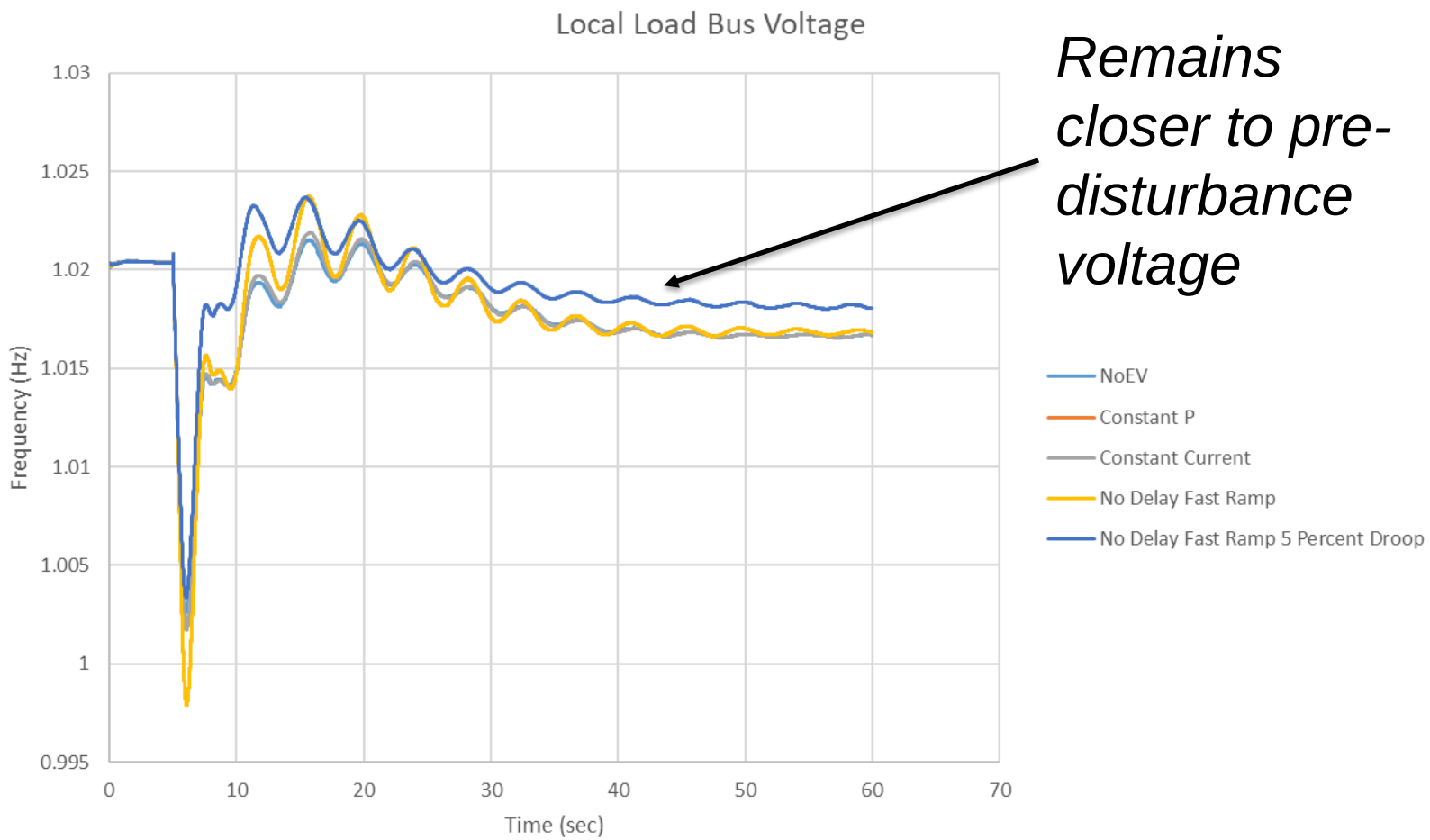
Better trajectory with 5% drop

EV model Output



Better oscillatory response with 5% drop

High Side Transformer Voltage



Remains closer to pre-disturbance voltage

5% droop > noEV = constI > constP

Draft Conclusions and Recommendations

- Adding more constant power load to the system reduces the small signal stability and frequency response performance.
  - Not just an EV finding. EVs should operate in Constant Current over Constant Power. This confirms the CMC report findings
- Adding a 5% droop response to load significantly improves small signal stability as well as arresting the frequency decline. This confirms the CMC report findings
  - Sharing the reduction of charging across all models reduces load by ~400 MW, but individual record reduced 3 MW.
- EV chargers should implement a droop characteristic of no lesser than 5% and a reasonable deadband (*17mHz*)
  - May be altered depending on droop sensitivity study
  - Deadband can be altered based on Interconnection

Future Work

July 2023

- Resource loss performance - In progress
- Droop control sensitivities – In progress
- Frequency response sensitivities – In progress
- Detection delay sensitivity – in progress
- Addition of “no-EV” baselines – Complete

July 2023+

- Large scale versus small scale EV deployment
- Additional FIDVR sensitivities
- Angular stability sensitivity
- Low Inertia/weak grid cases

Questions and Answers

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