ERO Enterprise Endorsed Implementation Guidance

Reliability and Security Technical Committee (RSTC)

System Protection and Control Working Group (SPCWG)

PRC-019 Implementation Guidance: Coordination of Generating Unit or Plant Capabilities, Voltage Regulating Controls and Protection

Requirements R1 & R2

October 18, 2022

Table of Contents

Introduction 3
Goal/Problem Statement 3
Scope 3
Reliability Standard 4
Requirement R1 4
Synchronous Generation Example 4
Synchronous Condenser Example 9
Dispersed Power Producing Resources Example 14
Requirement R2 18
Equipment or Protection System Change Example 18
Periodic Review 18

Introduction

This document provides guidance related to coordination between a generator voltage control system and their associated protection functions. The standard requirements ensure that an entity coordinates voltage control limiters with protection systems and protection systems with machine equipment capabilities before placing a generating unit into service. It is also intended to establish reasonable assumptions that may be used in the calculations to meet the intent of this standard.

Goal/Problem Statement

This document identifies the different variables and system conditions associated with generation control and protection coordination. Evolving technologies within generation resources have inherent differences in the way they control voltage and protect their systems. The diversity of the systems throughout the industry may require analysis from a different vantage point.

Scope

This Implementation Guidance applies to Generator Owners (GO) and Transmission Owners (TO) who are seeking to demonstrate compliance with PRC-019-2 Requirements R1 and R2.

This document provides examples showing coordination of voltage control systems, Protection Systems and equipment capabilities for the following types of resources:

- Traditional Synchronous Generation
- Type 1 & Type 2 Wind Turbine
- Inverter Based Resources:
    - Type 3 Doubly Fed Induction Generator (DFIG) or Doubly Fed Asynchronous Generator (DFAG) Wind Turbine
    - Type 4 Full Conversion Wind Turbine
    - Photovoltaic (Solar) System
    - Battery Energy Storage Systems (BESS)

Please reference the NERC SPCWG PRC-019 Technical Reference document for example calculations utilizing various engineering concepts. These examples DO NOT represent the only method for showing compliance. They are simply an example of the engineering principles and philosophies an entity may

consider for compliance with the standard. Different generator designs and protection schemes may require modifications to the calculations. An entity should not blindly copy the methodology outlined in the NERC SPCWG PRC-019 Technical Reference document; but should have an in-depth understanding of the holistic generation system before making specific coordination decisions.

Reliability Standard

Requirement R1

At a maximum of every five calendar years, each Generator Owner and Transmission Owner with applicable Facilities shall coordinate the voltage regulating system controls, (including in-service[1] limiters and protection functions) with the applicable equipment capabilities and settings of the applicable Protection System devices and functions.

1.1. Assuming the normal automatic voltage regulator control loop and steady-state system operating conditions, verify the following coordination items for each applicable Facility:

1.1.1. The in-service limiters are set to operate before the Protection System of the applicable Facility in order to avoid disconnecting the generator unnecessarily.

1.1.2. The applicable in-service Protection System devices are set to operate to isolate or de-energize equipment in order to limit the extent of damage when operating conditions exceed equipment capabilities or stability limits.

Evolving technologies within generation resources have inherent differences in the way they control voltage and provide protect of equipment. The examples provide different vantage points for analysis of diverse systems throughout the industry.

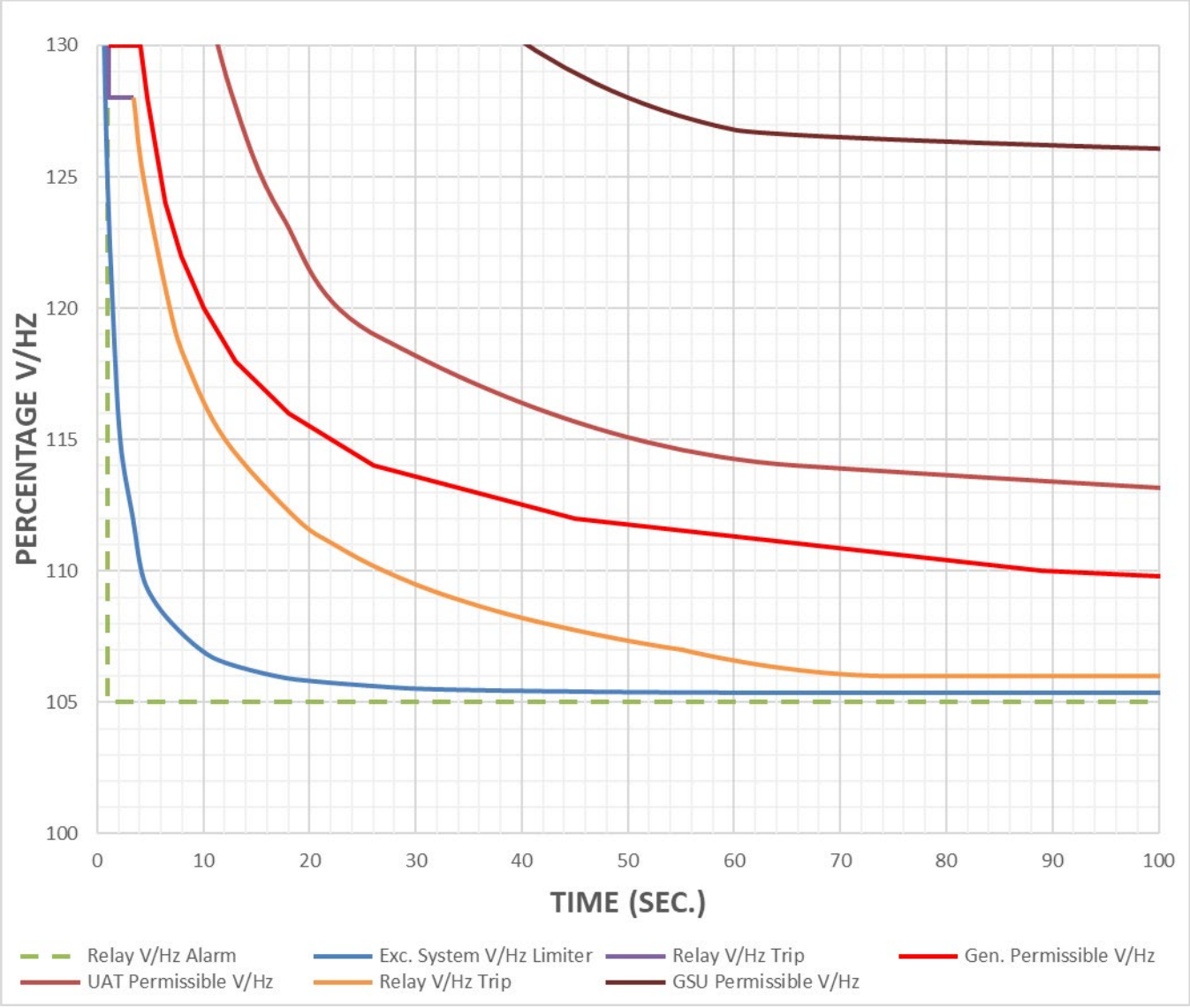
Synchronous Generation Example

To demonstrate compliance with PRC-019-2 R1 for a synchronous generator, a series of plots should be created that demonstrate:

- Generator Stator Overflux Coordination
- Generator Overexcitation Coordination
- Generator Underexcitation Coordination on a P-Q plane or R-X plane

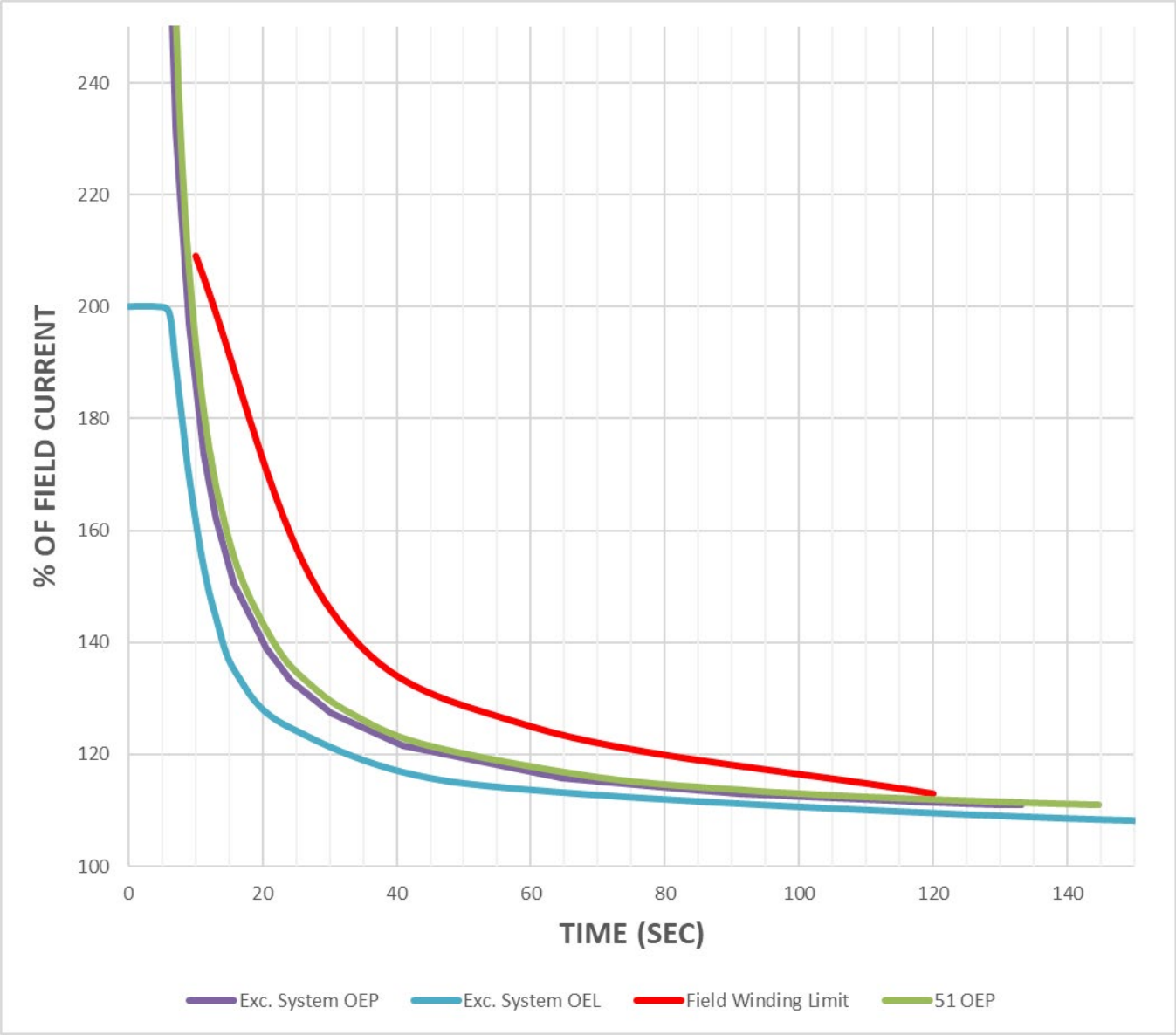
[1] Limiters or protection functions that are installed and activated on the generator or synchronous condenser.

The generator stator overflux diagram consists of excitation system V/Hz limiter coordination with relay and excitation system V/Hz protection. In addition, the illustration shows the coordination between the relay and excitation system V/Hz protection with the generator, GSU, and UAT overexcitation capability.



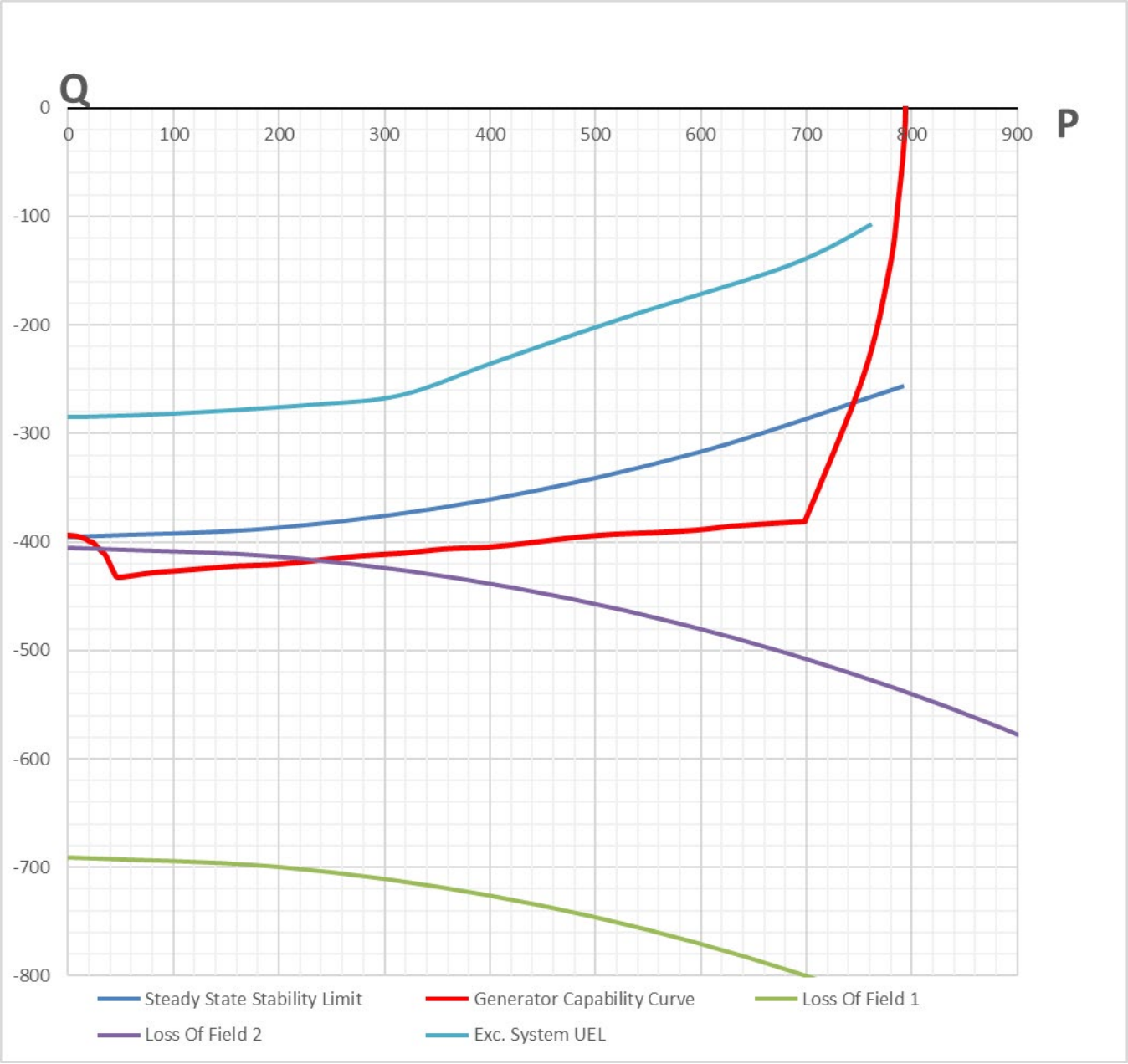
Generator Stator Overflux Coordination

The generator overexcitation diagram consists of the excitation system limiter coordination with relay and excitation system protection. In addition, the illustration shows the coordination between the relay and excitation system OEP protection with the field winding thermal capability.

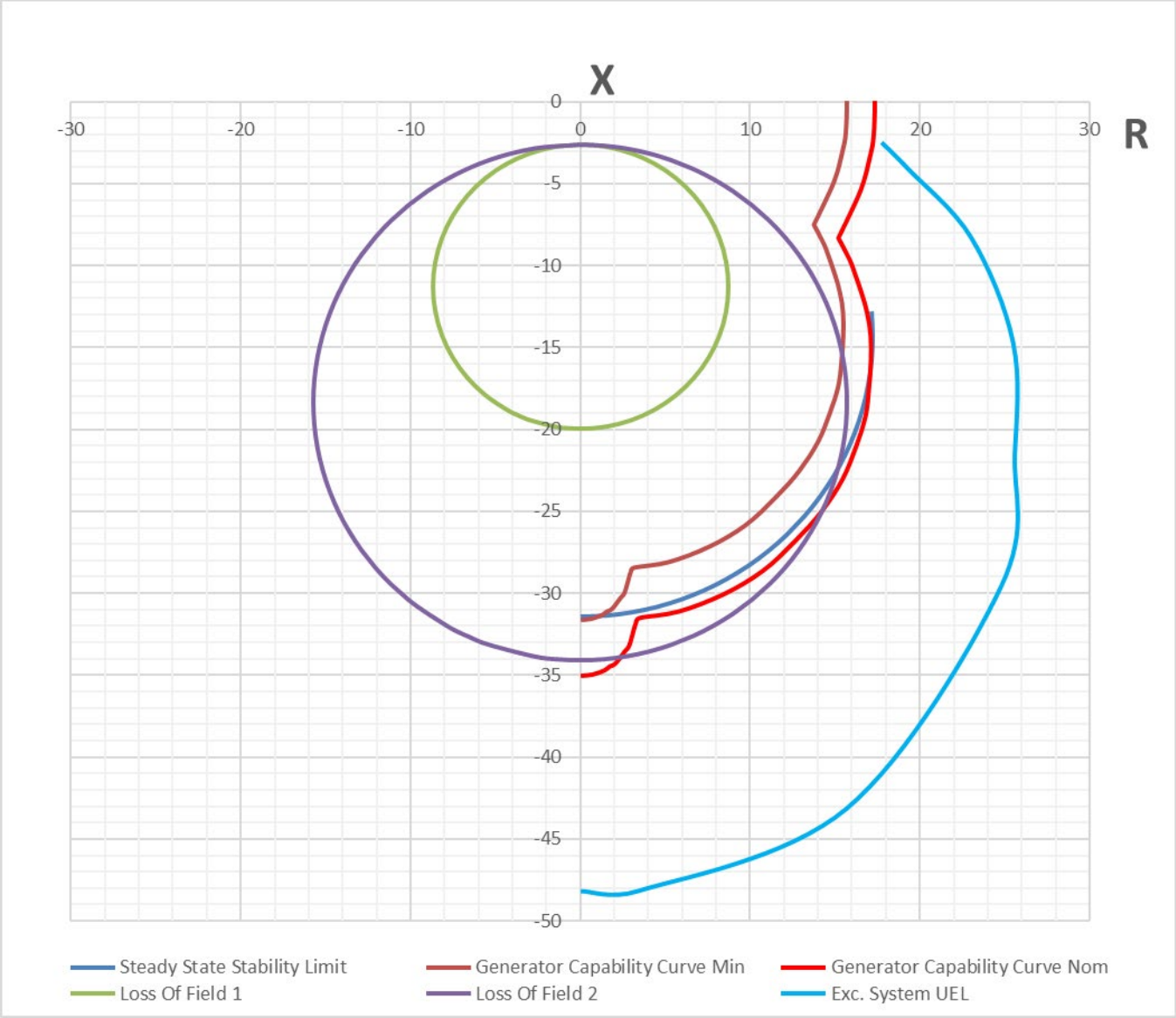


Generator Overexcitation Coordination

The Generator Underexcitation Coordination on a P-Q plane or R-X plane consists of excitation system UEL coordination with loss of field protection. In addition, the illustration shows the coordination between the loss of field protection scheme with the stator end-winding thermal capability.



Generator Underexcitation Coordination (P-Q Plane)



Generator Underexcitation Coordination (R-X Plane)

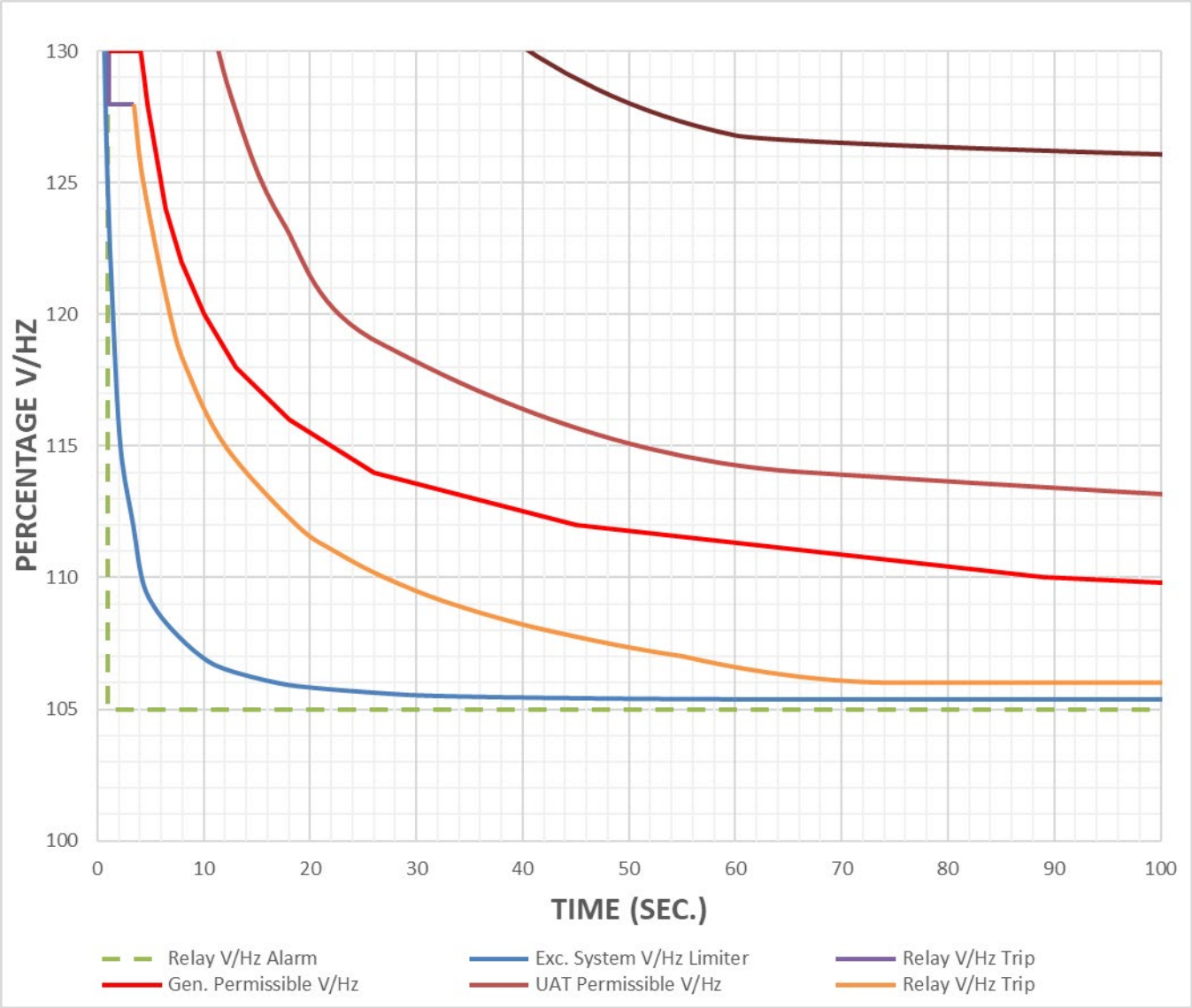
For information on how to perform the calculations and examples of the calculations used to create these diagrams, please reference the NERC SPCWG PRC-019-2 Technical Reference Document located on the NERC website.

Synchronous Condenser Example

To demonstrate compliance with PRC-019-2 R1 for a synchronous condenser, a series of plots should be created that demonstrate:

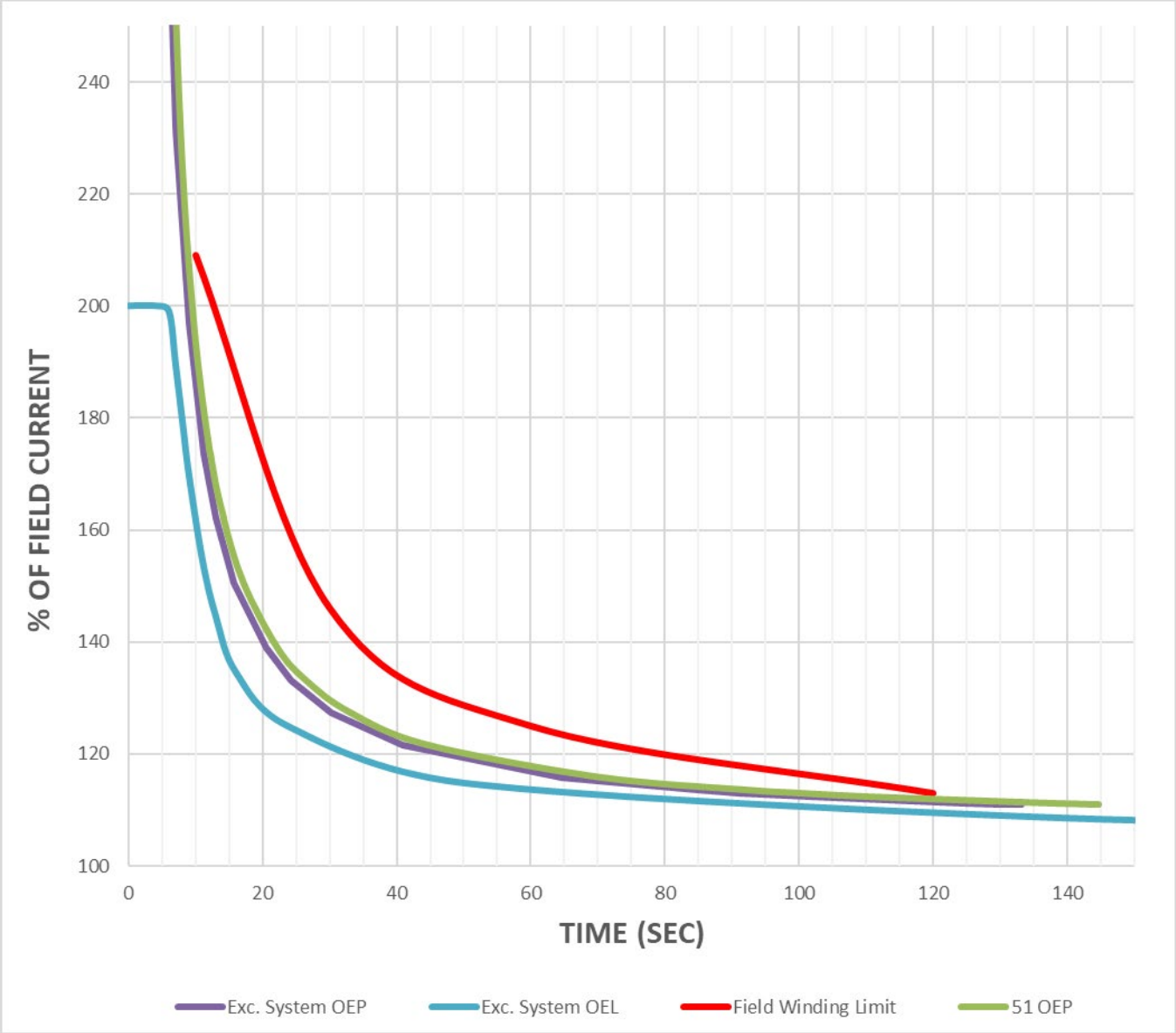
- Synchronous Condenser Stator Overflux Coordination
- Synchronous Condenser Overexcitation Coordination
- Synchronous Condenser Underexcitation Coordination on a P-Q plane or R-X plane

The synchronous condenser overflux coordination diagram consists of excitation system V/Hz limiter coordination with relay and excitation system V/Hz protection. In addition, the illustration shows the coordination between the relay and excitation system V/Hz protection with the condenser, GSU, and UAT overexcitation capability.



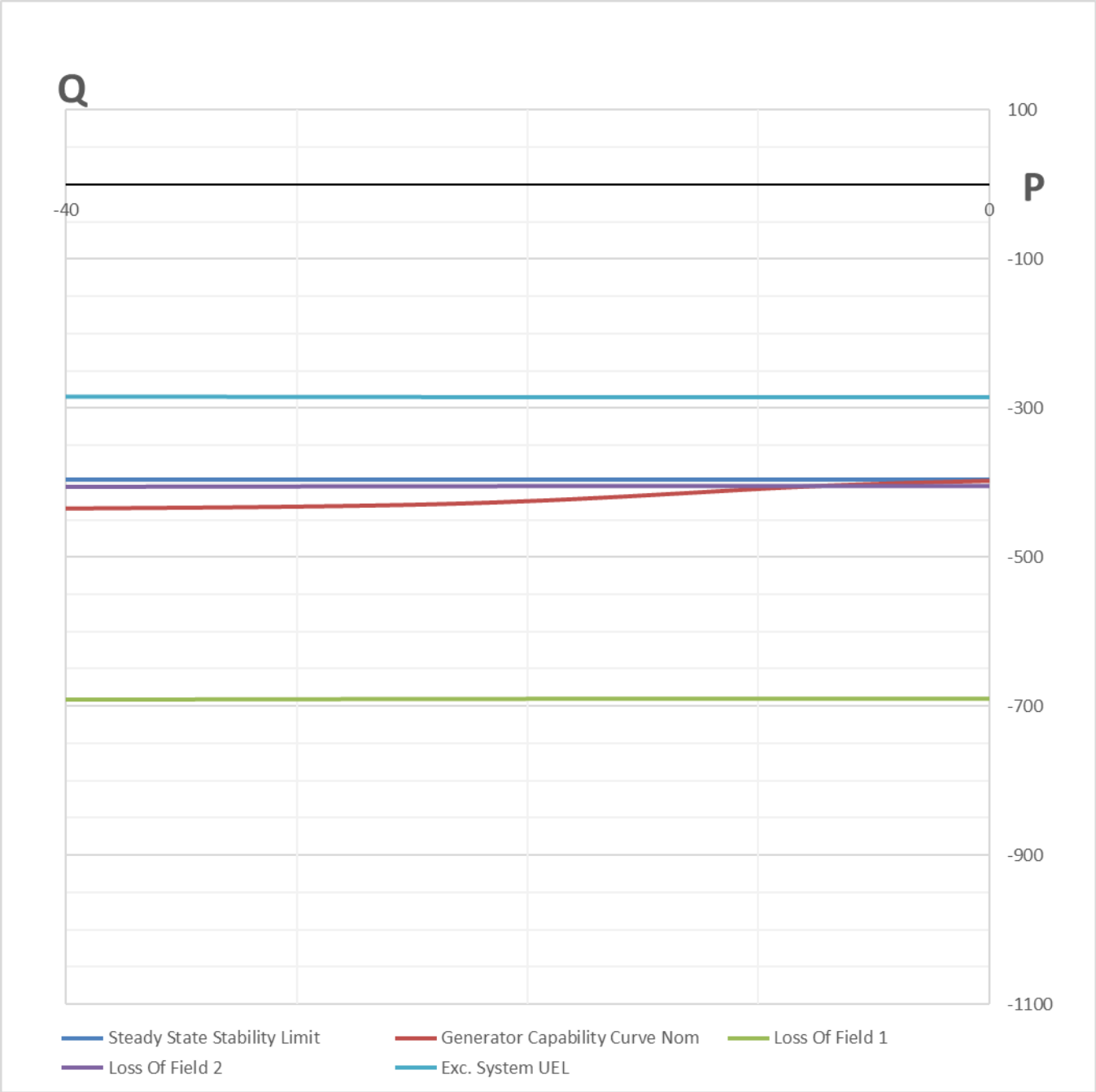
Synchronous Condenser Stator Overflux Coordination

The synchronous condenser overexcitation diagram consists of excitation system limiter coordination with relay and excitation system protection. In addition, the illustration shows the coordination between the relay and excitation system V/Hz protection with the field winding thermal capability.



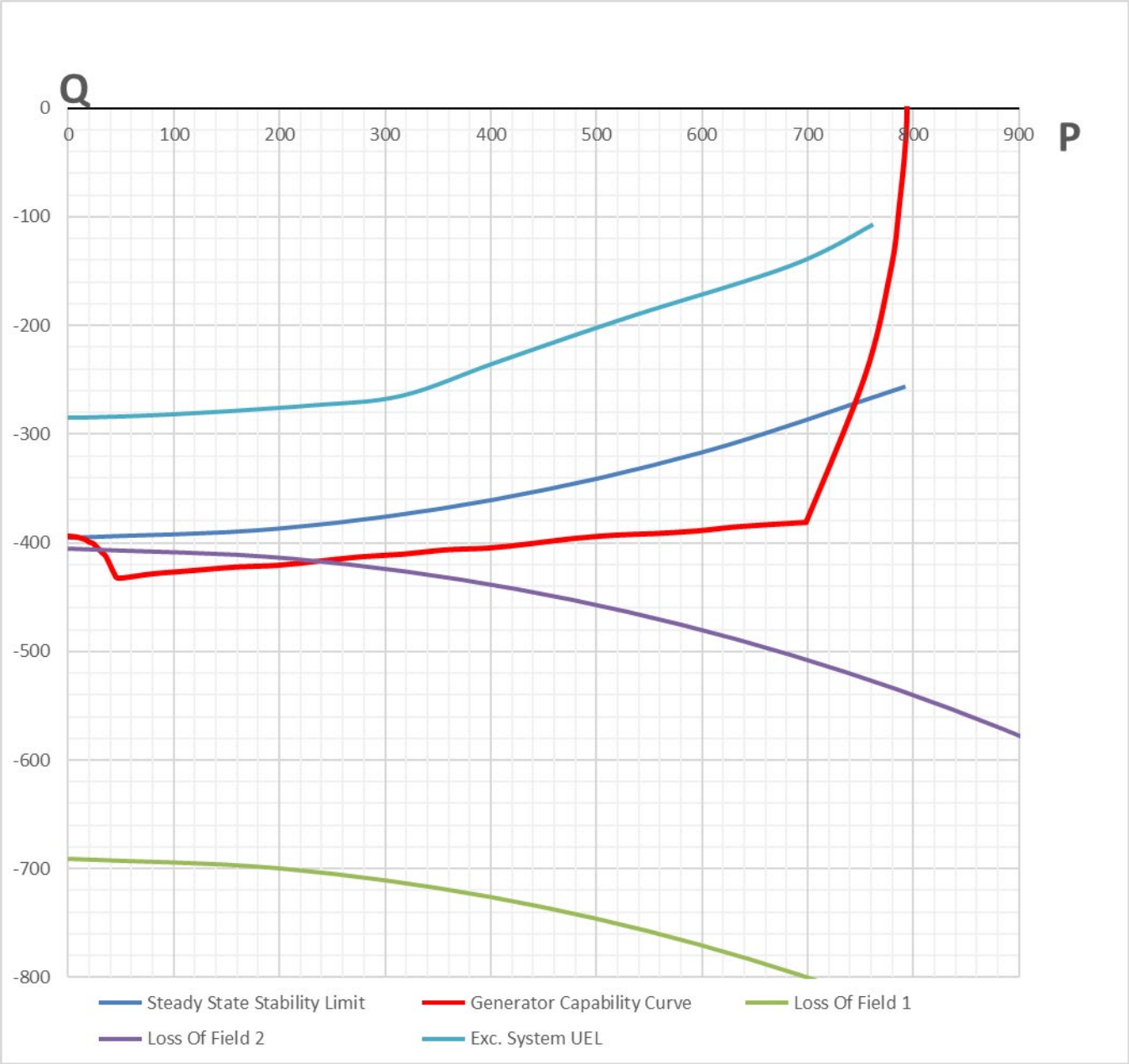
Synchronous Condenser Overexcitation Coordination

The synchronous condenser underexcitation diagram consists of excitation system UEL coordination with loss of field protection, with the synchronous condenser absorbing a small amount of real power from the grid to operate. In addition, the illustration shows the coordination between the loss of field protection scheme with the stator end-winding thermal capability.



Synchronous Condenser Underexcitation Coordination

An alternative method to plot synchronous condenser underexcitation coordination is to plot the coordination over the entire range of the D-curve.



Alternate Method of Plotting Synchronous Condenser Underexcitation Coordination

For information on how to perform the calculations and examples of the calculations used to create these diagrams, please reference the NERC SPCWG PRC-019-2 Technical Reference Document located on the NERC website.

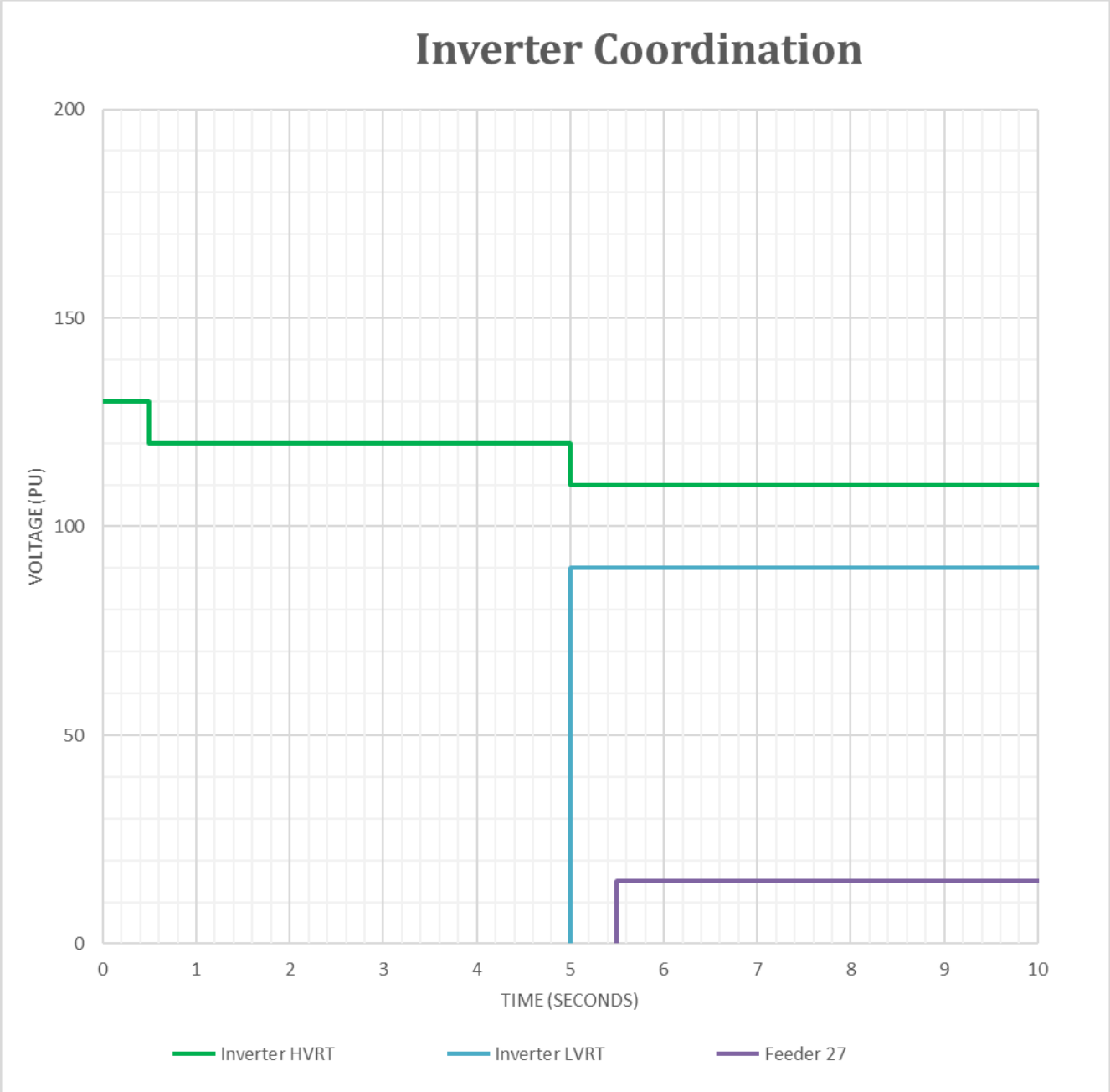
Dispersed Power Producing Resources Example

Dispersed power producing resource facilities are very different than synchronous machine facilities. Since they are not synchronous, they do not have excitation systems. Typically, dispersed power producing resource facilities just need to ensure coordination between their controls and the various high and low voltage tripping within the facility.

To demonstrate compliance with PRC-019-2 R1 for a dispersed power producing resource facility, a series of plots should be created that demonstrate:

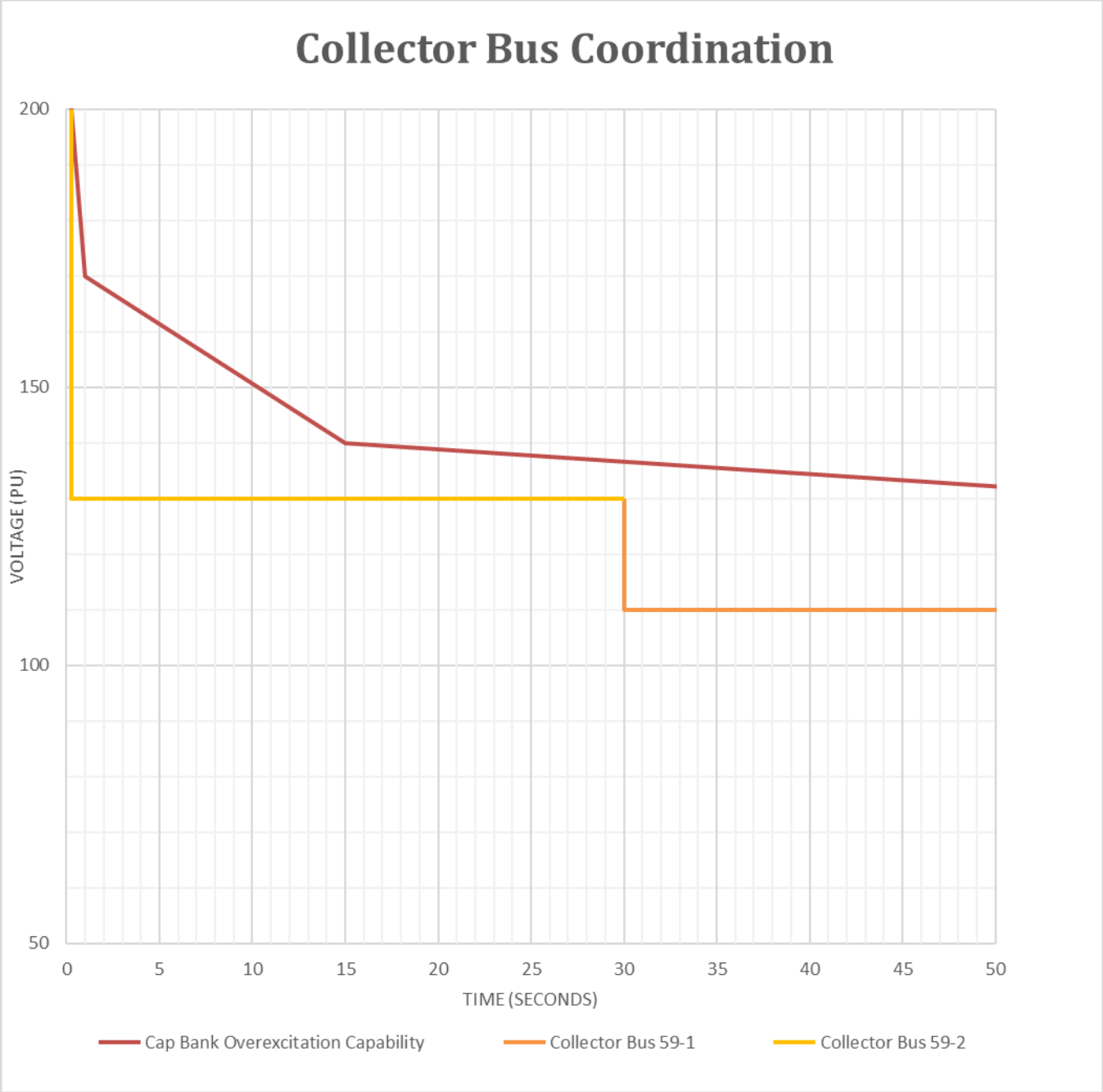
- Inverter Voltage Coordination
- Collector Bus Voltage Coordination
- Point of Interconnection (POI) Voltage Coordination

The inverter voltage coordination plot consists of inverter LVRT and HVRT coordination with feeder protection.



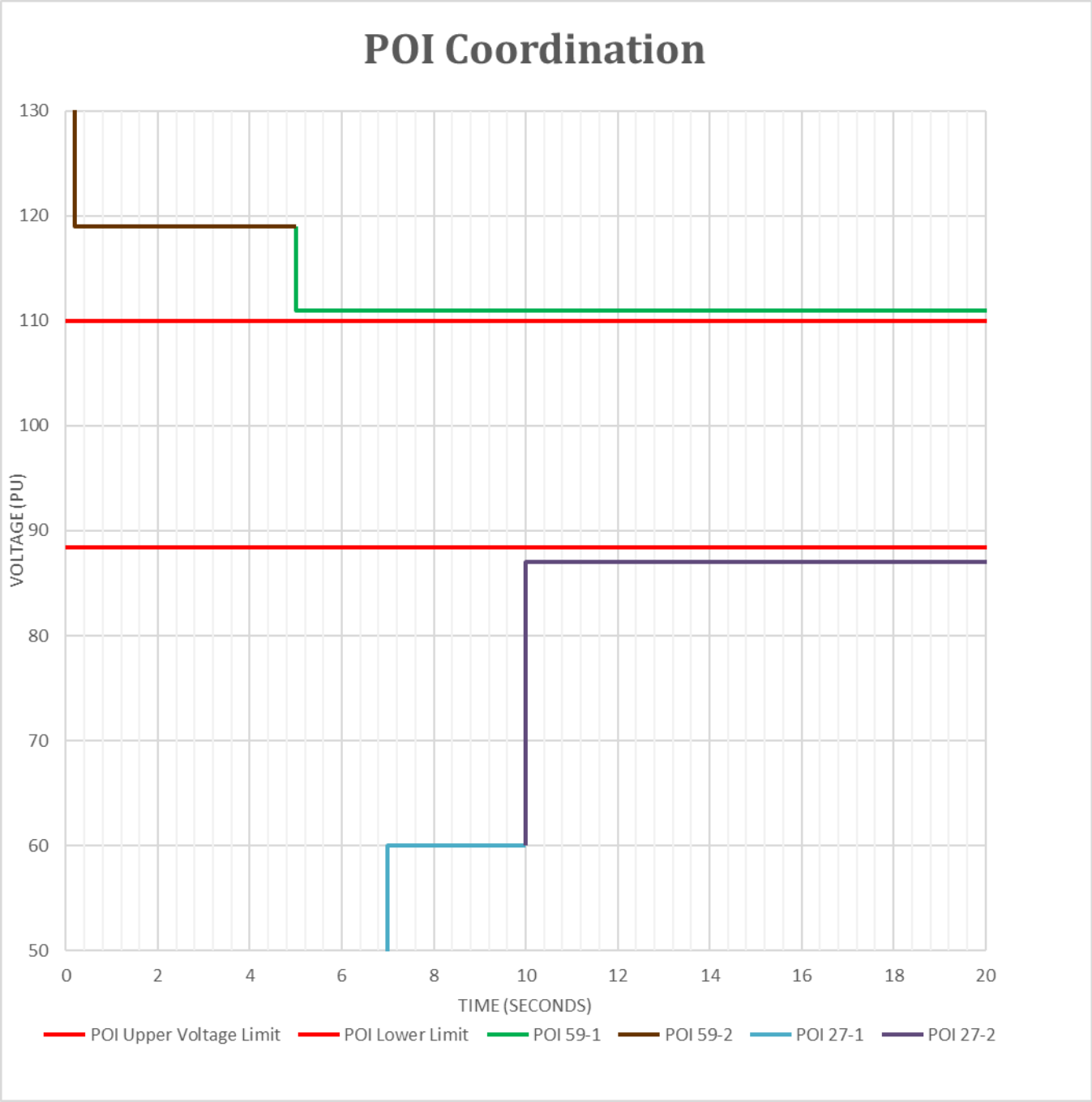
Inverter Voltage Coordination

The collector bus voltage coordination plot consists of voltage protection, associated with the collection bus, coordinated with any reactive device controls such as capacitor banks, SVCs or STATCOMs.



Collector Bus Voltage Coordination

The point of interconnection voltage coordination plot consists of voltage protection, associated with the high-side of the main power transformer, coordination with the interconnecting system capabilities.



Point of Interconnection Voltage Coordination

For information on how to perform the calculations and examples of the calculations used to create these diagrams, please reference the NERC SPCWG PRC-019-2 Technical Reference Document located on the NERC website.

Requirement R2

Within 90 calendar days following the identification or implementation of systems, equipment or setting changes that will affect the coordination described in Requirement R1, each Generator Owner and Transmission Owner with applicable Facilities shall perform the coordination as described in Requirement R1. These possible systems, equipment or settings changes include, but are not limited to the following:

- Voltage regulating settings or equipment changes;
- Protection System settings or component changes;
- Generating or synchronous condenser equipment capability changes; or
- Generator or synchronous condenser step-up transformer changes.

Equipment or Protection System Change Example

For equipment or protection system changes that have an impact on coordination, the entity shall perform the new coordination analysis before putting a generating unit back into service. For example, the replacement of an excitation system or generator relay requires an entity to ensure proper coordination with limiters and equipment capabilities before putting the machine back on-line. Without this verification, a generation unit can be tied back into the grid and become susceptible to damage, misoperations, and system stability issues.

Periodic Review

The SPCWG will review and update this Implementation Guidance for accuracy and applicability whenever the PRC-019 Standard undergoes a new revision and submit the modified IG for endorsement. Additionally, if any changes are made to the SPCWG PRC-019 Technical Reference document, the IG will also be reviewed and if needed, resubmitted for endorsement.