Standard Development Roadmap

This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.

Development Steps Completed:

1. SAR posted for comment (April 20–May 21, 2007).
2. Revised SAR and response to comments posted.
3. Revised SAR and response to comments approved by SC (June 14, 2007).
4. SDT appointed on (August 18, 2007).
5. Posted first draft of standard for a 30 day comment period June 15 –July 15, 2011

Proposed Action Plan and Description of Current Draft:

This is the ~~first~~second draft of the proposed standard including Time Horizons, Data Retention, Violation Risk Factors, and Violation Severity Levels; and is being submitted for a ~~30~~45-day concurrent formal comment period and initial ballot.

Future Development Plan:

Anticipated Actions	Anticipated Date
1. ~~Post first~~Develop responses to comments and develop second version draft ~~revision of~~ standard.	~~April May~~July 2011 – February 2012
2. Post response to comments and ~~second version draft revision of~~conduct a formal 45 day comment period with concurrent initial ballot for the revised standard.	~~July – August 2011~~February - March 2012
3. ~~Post response to comments and request authorization~~Develop responses to ballot ~~the revised standard~~comments.	~~September - October 2011~~March - June 2012
4. ~~Conduct initial~~Post response to comments and conduct successive ballot.	~~November 2011~~June 2012
5. ~~Post response~~Develop responses to ballot comments.	~~December 2011~~June – July 2012
6. ~~Conduct~~Post responses to comments and conduct recirculation ballot.	~~January~~August 2012
7. BOT adoption.	~~February~~September 2012
8. File with regulatory authorities.	~~March~~November 2012

A. Introduction

1. Title: Coordination of Generating Unit or Plant Capabilities, Voltage Regulating Controls ~~with Generating Unit or Plant Capabilities,~~ and Protection

2. Number: PRC-019-1

3. Purpose: To ~~improve the reliability of the Bulk Electric System by preventing tripping of generating units and generating Facilities due to mis-~~verify coordination of generating unit ~~and generating~~ Facility or synchronous condenser voltage regulating controls ~~and~~, limit functions ~~with generator~~, equipment capabilities and ~~protection system~~ Protection System settings.

4. Applicability:

4.1. Functional Entities

4.1.1 Generator Owner

4.1.2 Transmission Owner that owns synchronous condenser(s)

4.2. Facilities

For the purpose of this standard, the term, "applicable Facility" shall mean any one of the following:

4.2.1 Individual generating unit ~~or synchronous condenser >~~greater than 20 MVA (gross nameplate rating) directly connected ~~at the point of interconnection at 100 kV or above~~to the bulk power system.

~~**4.2.1**~~**4.2.2** Individual synchronous condenser greater than 20 MVA (gross nameplate rating) directly connected to the bulk power system.

~~**4.2.2**~~**4.2.3** Generating plant ~~and generating Facility >~~/ Facility consisting of one or more units that are connected to the bulk power system at a common bus with total generation greater than 75 MVA (gross aggregate nameplate rating~~) connected at the point of interconnection at 100 kV or above.~~).

~~**4.2.3**~~**4.2.4** ~~Blackstart Resources~~Any generator, regardless of size ~~included in~~, that is a Blackstart Resource material to and designated as part of a Transmission Operator's restoration plan.

5. Effective Date:

5.1. In those jurisdictions where regulatory approval is required:

5.1.1 By the first day of the first calendar quarter, one calendar year following applicable regulatory approval each Generator Owner and Transmission Owner shall have verified at least 20~~%~~ percent of its applicable ~~units~~Facilities.

5.1.2 By the first day of the first calendar quarter, two calendar years following applicable regulatory approval each Generator Owner and Transmission Owner shall have verified at least 40~~%~~ percent of its applicable ~~units~~Facilities.

5.1.3 By the first day of the first calendar quarter, three calendar years following applicable regulatory approval each Generator Owner and Transmission Owner shall have verified at least 60~~%~~ percent of its applicable ~~units~~Facilities.

5.1.4 By the first day of the first calendar quarter, four calendar years following applicable regulatory approval each Generator Owner and Transmission Owner shall have verified at least 80~~%~~ percent of its applicable ~~units~~Facilities.

5.1.5 By the first day of the first calendar quarter, five calendar years following applicable regulatory approval each Generator Owner and Transmission Owner shall have verified 100~~%~~ percent of its applicable ~~units~~Facilities.

5.2. In those jurisdictions where regulatory approval is not required:

5.2.1 By the first day of the first calendar quarter, one calendar year following Board of Trustees approval each Generator Owner and Transmission Owner shall have verified at least 20~~%~~ percent of its applicable ~~units~~Facilities.

5.2.2 By the first day of the first calendar quarter, two calendar years following Board of Trustees approval each Generator Owner and Transmission Owner shall have verified at least 40~~%~~ percent of its applicable ~~units~~Facilities.

5.2.3 By the first day of the first calendar quarter, three calendar years following Board of Trustees approval each Generator Owner and Transmission Owner shall have verified at least 60~~%~~ percent of its applicable ~~units~~Facilities.

5.2.4 By the first day of the first calendar quarter, four calendar years following Board of Trustees approval each Generator Owner and Transmission Owner shall have verified at least 80~~%~~ percent of its applicable ~~units~~Facilities.

5.2.5 By the first day of the first calendar quarter, five calendar years following Board of Trustees approval each Generator Owner and Transmission Owner shall have verified 100 percent of its applicable Facilities.

B. Requirements

R1. Each Generator Owner and Transmission Owner with applicable Facilities shall coordinate ~~its generating unit and generating Facility~~ the voltage regulating system controls, (including In-service [1] limiters and protection functions) with the ~~generating unit and~~applicable Facility ~~or synchronous condenser~~ capabilities and ~~protective system~~Protection System settings~~; to include as applicable:~~. *[Violation Risk Factor: High] [Time Horizon: Long-term Planning]*

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

- In-service[2] excitation system and voltage regulating system control, limiters and protection functions
- In-service generator or synchronous condenser protection system settings

- Generating equipment or synchronous condenser capabilities
- Steady state stability limit

1.1. This coordination requires the following steps:

1.1.1. Verify that the limiters are set to operate before the protectionProtection System and the protectionProtection System is set to operate before conditions exceedcause damage to equipment capabilities (including the steady state stability limit) assuming normal AVR control loop and system steady state operating conditions.

1.1.2. Check that the settings determined in StepPart 1.1.1 are applied to the in-service equipment.

M1.1R2. Each Generator Owner and Transmission Owner shall verify the existence of the coordination identified in Requirement R1 at least once every five years or within 90 calendar days following the identification or implementation of systems, equipment or setting changes that are expected to affect this coordination, including but not limited to the following *[Violation Risk Factor: High] [Time Horizon: Long-term Planning]*:

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

C. Measures

M1. Each Generator Owner and Transmission Owner will have evidence, such as example plotsevidence provided in PRC-019 Section G, to show that its generating unit and generatingapplicable Facility or synchronous condenser excitation system and voltage regulating system controls and protectionProtection System functions are coordinated with the generating unit and generatingapplicable Facility capabilities and protective systemProtection System settings applied to in-service equipment as specified in Requirement R1. As applicable, this may include the following:

- In service excitation system and voltage regulating system control, limiters and protection functions
- In-service generator or synchronous condenser protection system settings
- , Section 1.1, and one previous dated set of evidence that demonstrates the latestGenerator or synchronous condenser capabilities, or

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

- Steady state stability limit.

The coordination ~~review has been done within~~should include 1) verifying the ~~intervals specified in Requirement R1, Section 1.2. If~~in-service limiters are set to operate before the ~~latest coordination review is performed due~~protection and the protection is set to ~~a change in the~~ operate before conditions cause damage to equipment assuming normal AVR control loop and system steady state operating conditions, and 2) verifying the desired settings are applied to the in-service equipment ~~or settings that changes the coordination, the~~ .

M2. Each Generator Owner and Transmission Owner with applicable Facilities will have evidence ~~(such as a work order) that demonstrates when~~ of the ~~change was implemented~~coordination review required by the events listed in Requirement R2. This evidence should include dated documentation that demonstrates the specified intervals in Requirement R2 are met.

D. Compliance

1. Compliance Monitoring Process

1.1. Compliance Enforcement Authority

Regional Entity

1.2. ~~Data~~Evidence Retention

The following evidence retention periods identify a period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention specified below is shorter than the time since the last compliance audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Owner and Transmission Owner shall keep data or evidence to show compliance as identified below unless directed by its Compliance Enforcement Authority to retain specific evidence for a longer period of time as part of an investigation:

- The Generator Owner and Transmission Owner shall retain ~~the latest and the prior~~ evidence of compliance with ~~Requirement~~Requirements R1~~, Measure~~ and R2, Measures M1 and M2 for six years.

If a Generator Owner or Transmission Owner is found non-compliant, it shall keep information related to the non-compliance until found compliant or for the time period specified above, whichever is longer.

The Compliance Enforcement Authority shall keep the last audit records and all requested and submitted subsequent audit records.

1.3. Compliance Monitoring and Assessment Processes

Compliance Audit

Self-Certification

Spot Checking

Compliance ~~Violation~~ Investigation

Self-Reporting

Complaint

1.4. Additional Compliance Information

None

2. Violation Severity Levels

R #	Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	N/A	N/A	N/A	The Generator Owner or Transmission Owner failed to verify the existence of the coordination specified in Requirement R1.
~~R1~~R2	The Generator Owner or Transmission Owner verified the coordination specified in Requirement R1 more than 90 calendar days but less than or equal to 100 calendar days following the identification or implementation of a change that ~~-~~affected the coordination. OR The Generator Owner or Transmission Owner verified the coordination specified in Requirement R1 more than 5years but less than or equal to 5 years and 4	The Generator Owner or Transmission Owner verified the coordination specified in Requirement R1 more than 100 calendar days but less than or equal to 110 calendar days following the identification or implementation of a change that affected the coordination. OR The Generator Owner or Transmission Owner verified the coordination specified in Requirement R1 more than 5years and 4 months but less than or equal to 5	The Generator Owner or Transmission Owner verified the coordination specified in Requirement R1 more than 110 calendar days but less than or equal to 120 calendar days following the identification or implementation of a change that affected the coordination. OR The Generator Owner or Transmission Owner verified the coordination specified in Requirement R1 more than 5years and 8 months but less than or equal to 6	The Generator Owner or Transmission Owner failed to verify the existence of the coordination specified in Requirement R1 ~~at least once every five years.~~ within 121 calendar days following the identification or implementation of a change that affected the coordination. OR The Generator Owner or Transmission Owner failed to verify the existence of the coordination specified in Requirement R1 ~~within 121 calendar days following the~~

	months.	years and 8 months.	years.	~~identification or implementation of a change that affected the coordination.~~ in more than 6 years.

E. **Regional Variances**

None.

F. **Associated Documents**

~~None.~~

"Underexcited Operation of Turbo Generators", AIEE Proceedings T Section 881, Volume 67, 1948, Appendix 1, C. G. Adams and J. B. McClure.

Reimert, Donald, Protective Relaying For Power Generation Systems, Boca Raton, FL, Taylor & Francis, 2006

Version History

Version	Date	Action	Change Tracking

G. **Reference**

Examples of Coordination

The evidence of coordination associated with Requirement R1 may be in the form of ~~one or more plots including (but not limited to):~~:

- P-Q Diagram (Example in Attachment 1), or
- R-X Diagram (Example in Attachment 2), or
- Inverse Time Diagram (Example in Attachment 3) or,
- ~~These plots contain~~Equivalent tables or other evidence

This evidence should include the equipment capabilities~~,~~ and the operating region for the limiters and protection ~~function such as; under-excitation limiters, steady state stability limits, or loss of field protection curves. Additional limiters and protection function that are installed and in-service can be incorporated as an Inverse Time Limit/Protection~~

~~Characteristic Plot (Attachment 3) or into the Generator Reactive Capability Curve Plot or an R-X diagram plot, identified above.~~functions

Equipment limits, types of limiters and protection functions which could be coordinated include~~:~~ (but are not limited to):

- Field over-excitation limiter and associated protection functions.
- Inverter over current limit and associated protection functions.
- Field under-excitation limiter and associated protection functions.
- Generator or synchronous condenser reactive capabilities.
- Volts per hertz limiter and associated protection functions.
- Stator over-voltage protection system settings.
- Generator and transformer volts per hertz capability.
- Time vs. field current or time vs. stator current.
- Converter over-temperature limiter and associated protection function.

NOTE: This listing is for reference only. This standard does not require the installation or activation of any of the above limiter or protection functions.

For the coordination required by this standard, the Steady State Stability Limit (SSSL) is the limit to synchronous stability in the under-excited region with fixed field current.

On a P-Q diagram using X_d as the direct axis saturated synchronous reactance of the generator, X_s as the equivalent reactance between the generator terminals and the "infinite bus" including the reactance of the generator step-up transformer and V_g as the generator terminal voltage (all values in per-unit), the SSSL can be calculated as an arc with the center on the Q axis with the magnitude of the center and radius described by the following equations

$$C = V^2_g/2*(1/X_s-1/X_d)$$

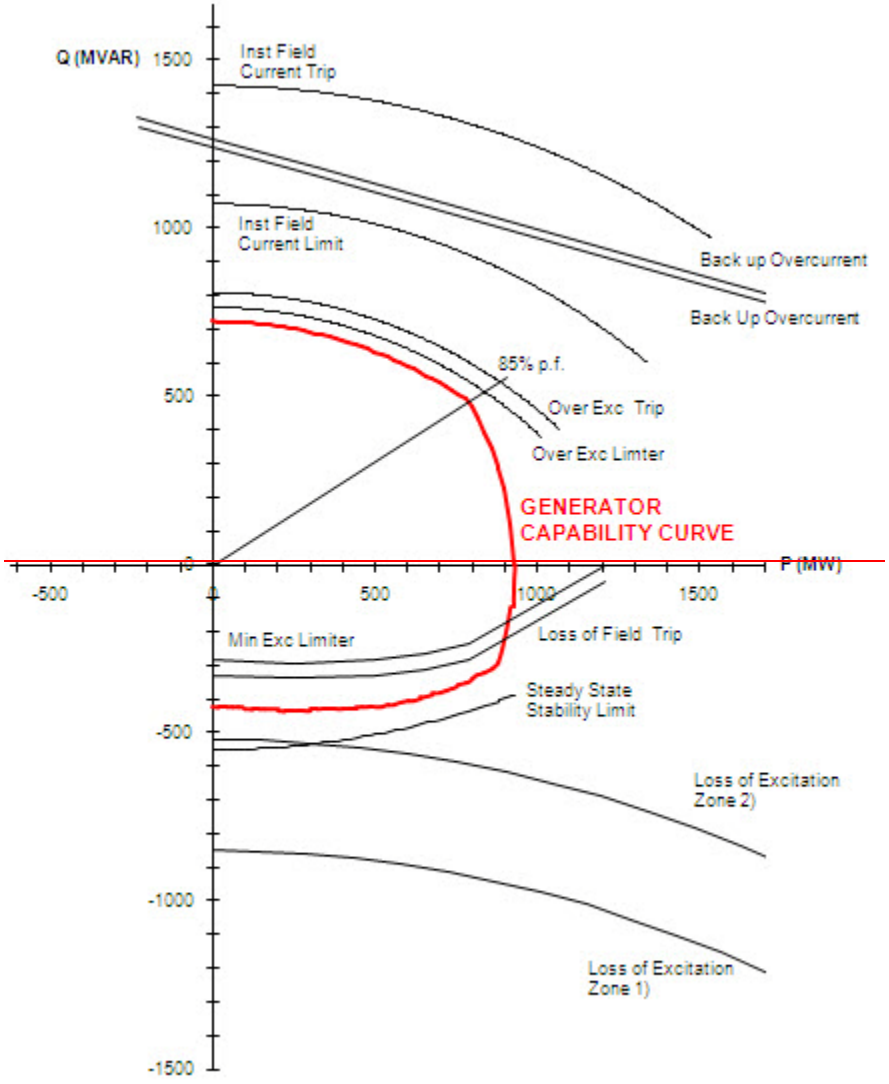
$$R = V^2_g/2*(1/X_s+1/X_d)$$

On an R-X diagram using X_d as the direct axis saturated synchronous reactance of the generator, and X_s as the equivalent reactance between the generator terminals and the "infinite bus" including the reactance of the generator step-up transformer the SSSL is an arc with the center on the X axis with the center and radius described by the following equations:

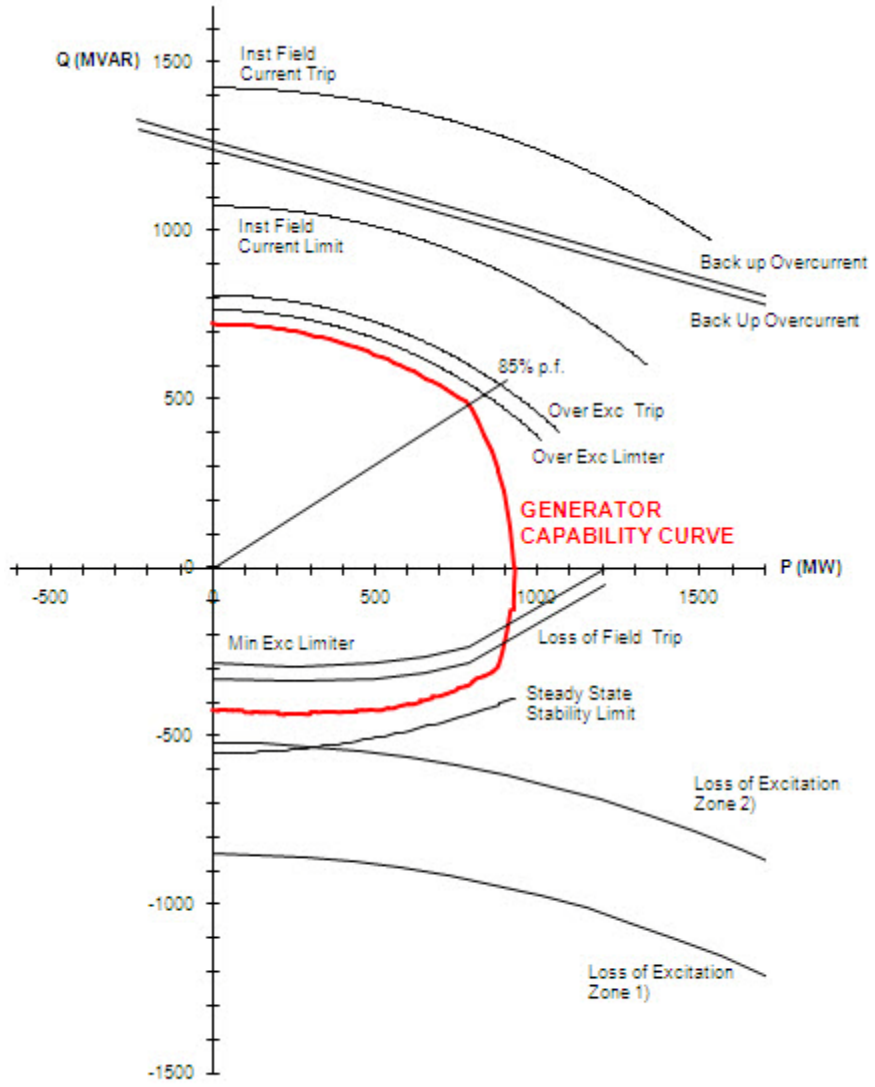
$$C = (X_d - X_s)/2$$

$$R = (X_d + X_s)/2$$

Attachment 1 – Example of Capabilities, Limiters and Protection on a P-Q Diagram at nominal voltage and frequency

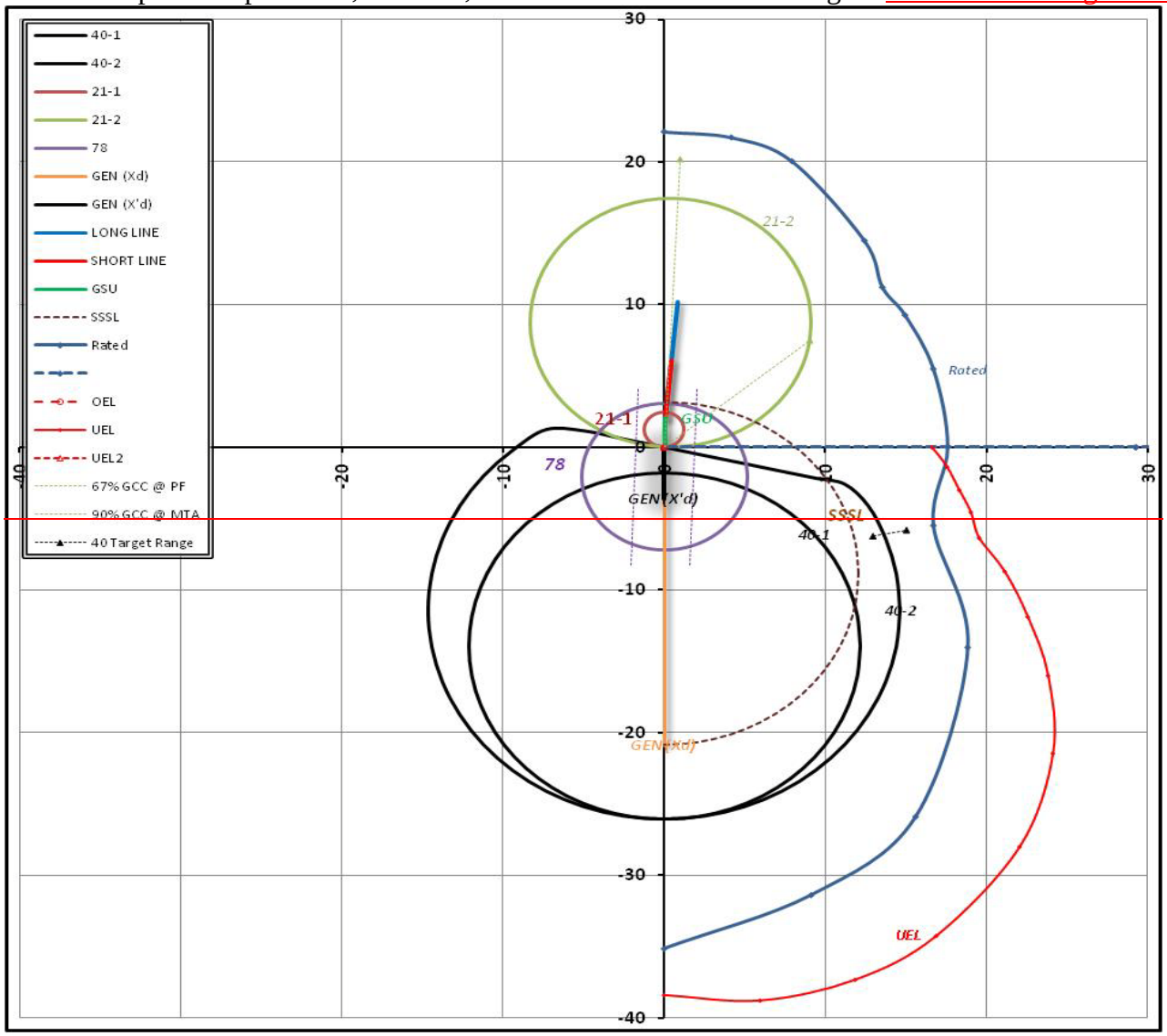


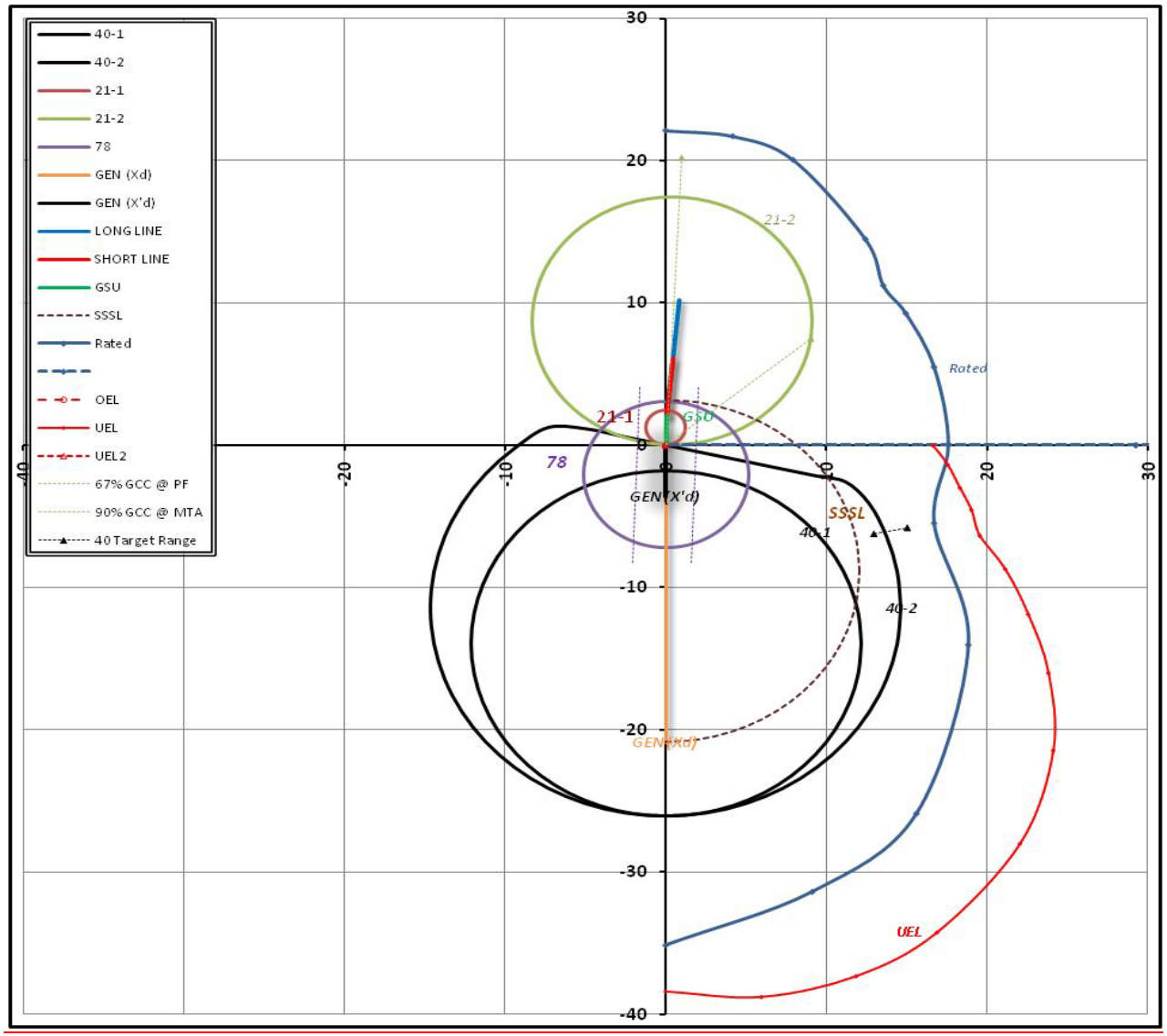
Example of Generator Capability Curve with Protection Elements Visible



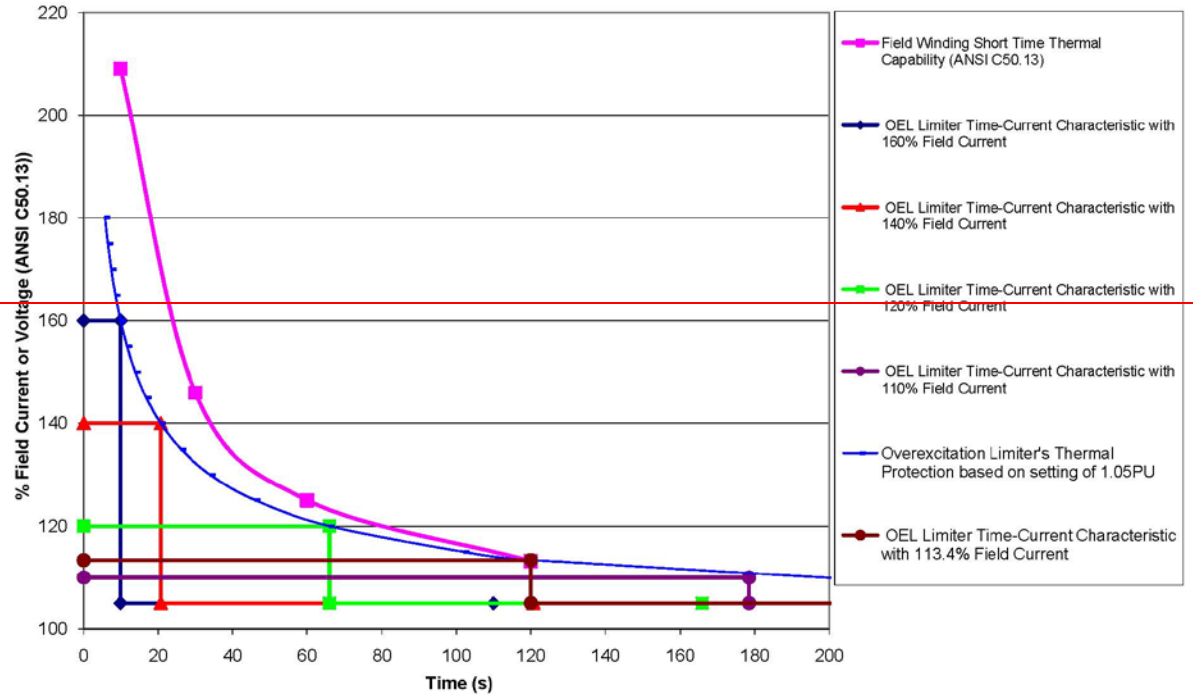
Example of Generator Capability Curve with Protection Elements Visible

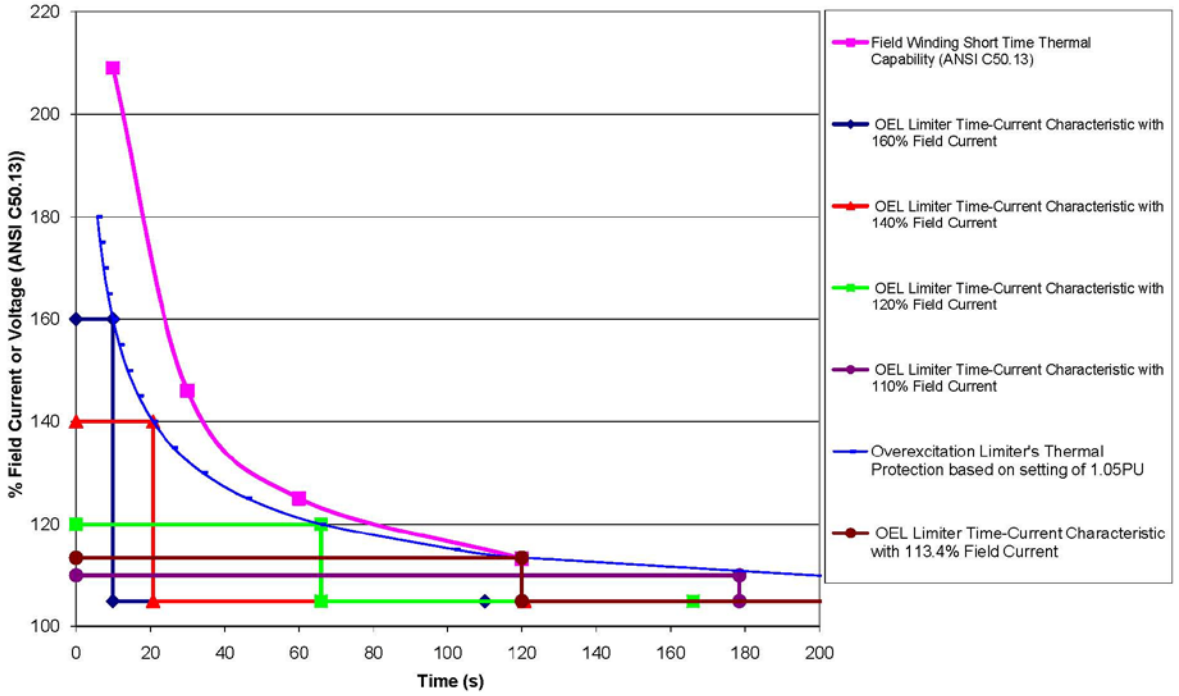
Attachment 2 – Example of Capabilities, Limiters, and Protection on an R-X Diagram at nominal voltage and frequency




40-1
40-2
21-1
21-2
78
GEN (Xd)
GEN (X'd)
LONG LINE
SHORT LINE
GSU
SSSL
Rated
OEL
UEL
UEL2
67% GCC @ PF
90% GCC @ MTA
40 Target Range
30
20
10
0
-10
-20
-30
-40
-40
-20
-10
0
10
20
30
21-2
Rated
21-1
GSU
78
GEN(X'd)
SSSL
40-1
40-2
GEN(Xd)
UEL

Attachment 3 - Example of Capabilities, Limiters, and Protection on an Inverse Time Characteristic Plot




220
200
180
160
140
120
100
% Field Current or Voltage (ANSI C50.13))
0
20
40
60
80
100
120
140
160
180
200
Time (s)
Field Winding Short Time Thermal Capability (ANSI C50.13)
OEL Limiter Time-Current Characteristic with 160% Field Current
OEL Limiter Time-Current Characteristic with 140% Field Current
OEL Limiter Time-Current Characteristic with 120% Field Current
OEL Limiter Time-Current Characteristic with 110% Field Current
Overexcitation Limiter's Thermal Protection based on setting of 1.05PU
OEL Limiter Time-Current Characteristic with 113.4% Field Current