

NERC Requirements for Setting Load-Dependent Power Plant Protection: PRC-025

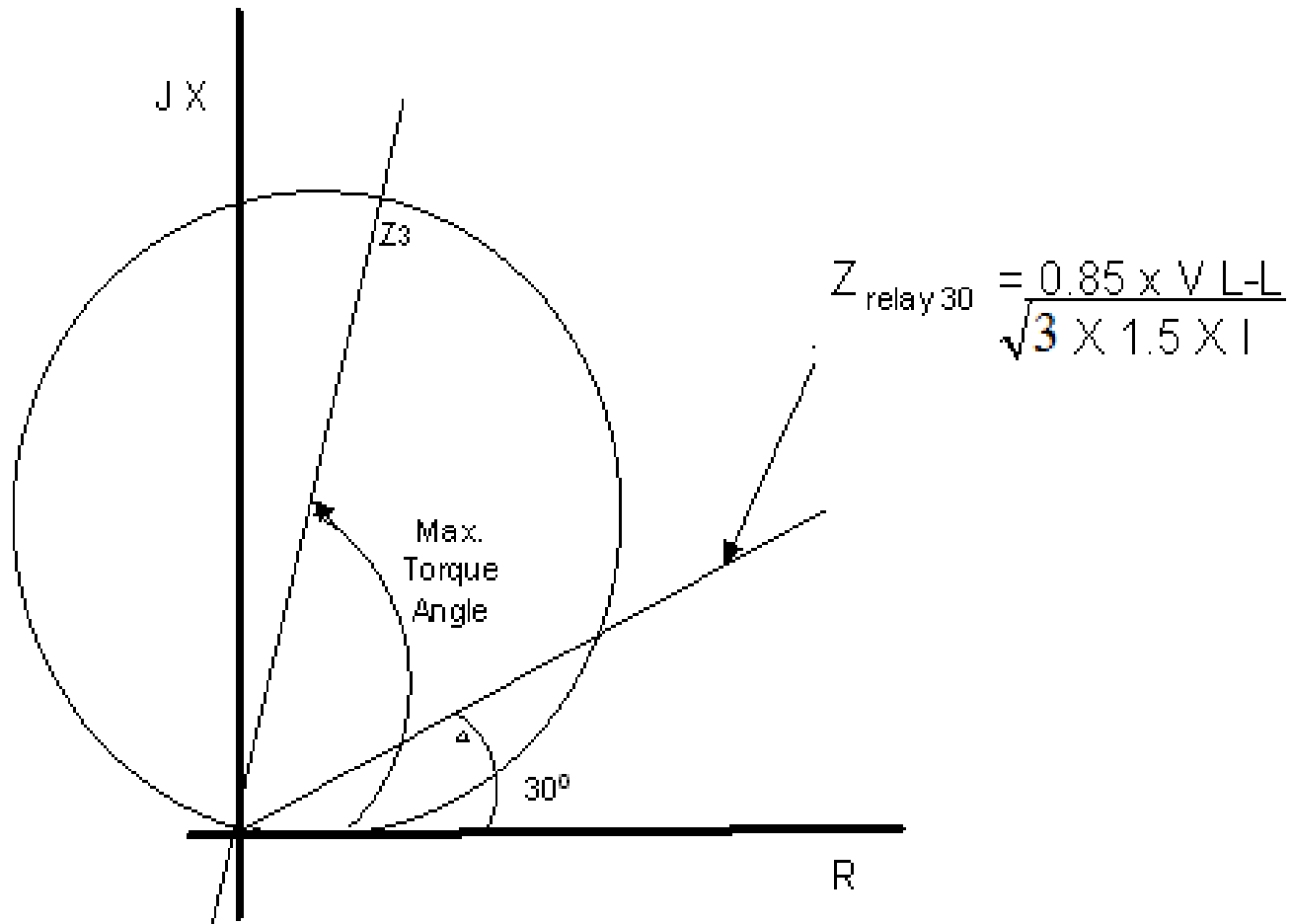
**Chuck Mozina, Consultant
Beckwith Electric Company**



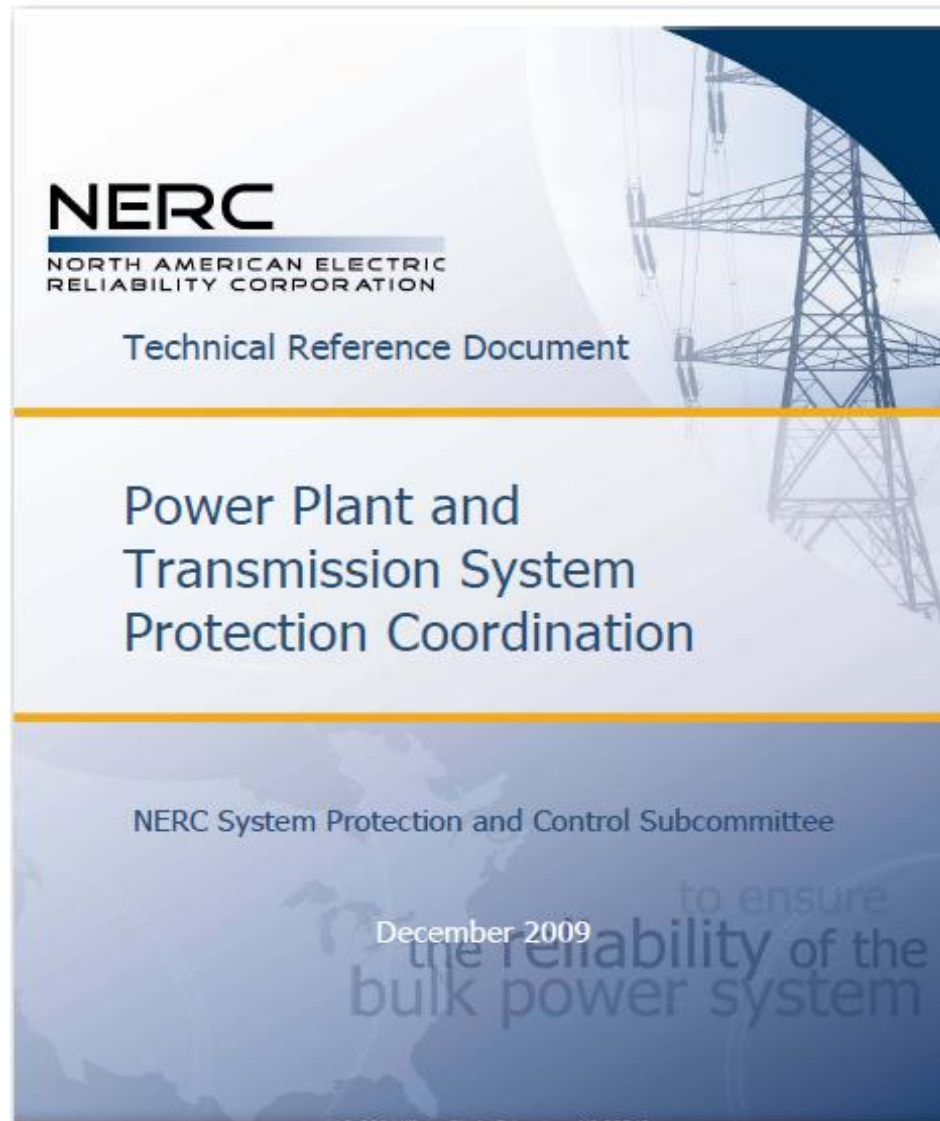
NERC Reliability Standards Transmission System – Generator Coordination - PRC-025-1

- **STANDARD APPROVED BY NERC – Aug. 2013**
- **PURPOSE:** To Set Load-Responsive Generator Protective Relays at Level such that Generators do not Trip During System Disturbances, Avoiding Damage to Generator.
- **APPLICABILITY:** Generator Owners, Generator Operators and Distribution Providers
- **APPLIES TO:**
 - + Generating Unit(s)
 - + Generator Step-Up Transformer.
 - + Auxiliary Transformers that Supply Auxiliary Power When Generator is On-Line
 - + Backup Line Protection

NERC PRC-023 – Transmission System Loadability

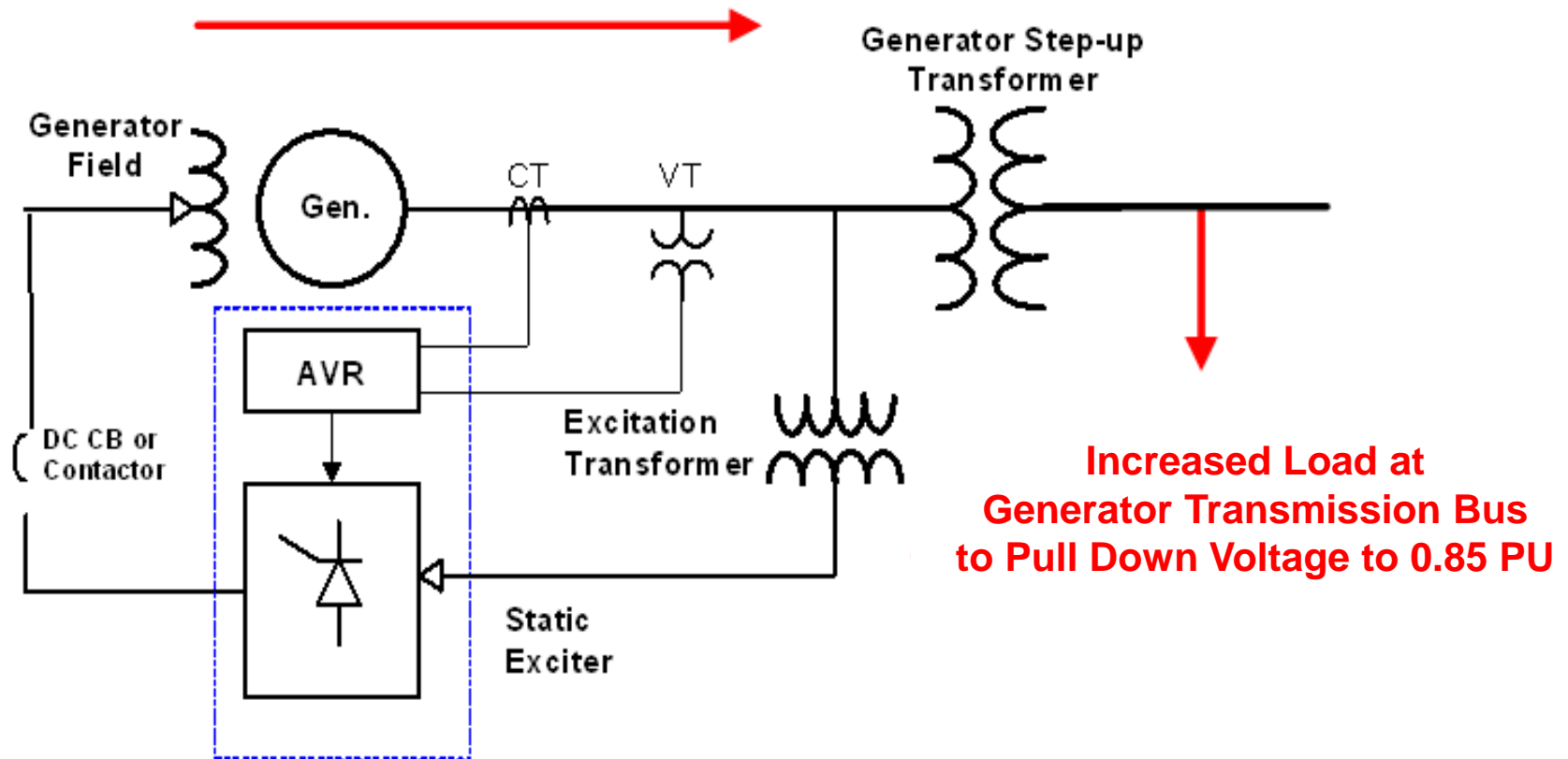


NERC Generator Setting Guide

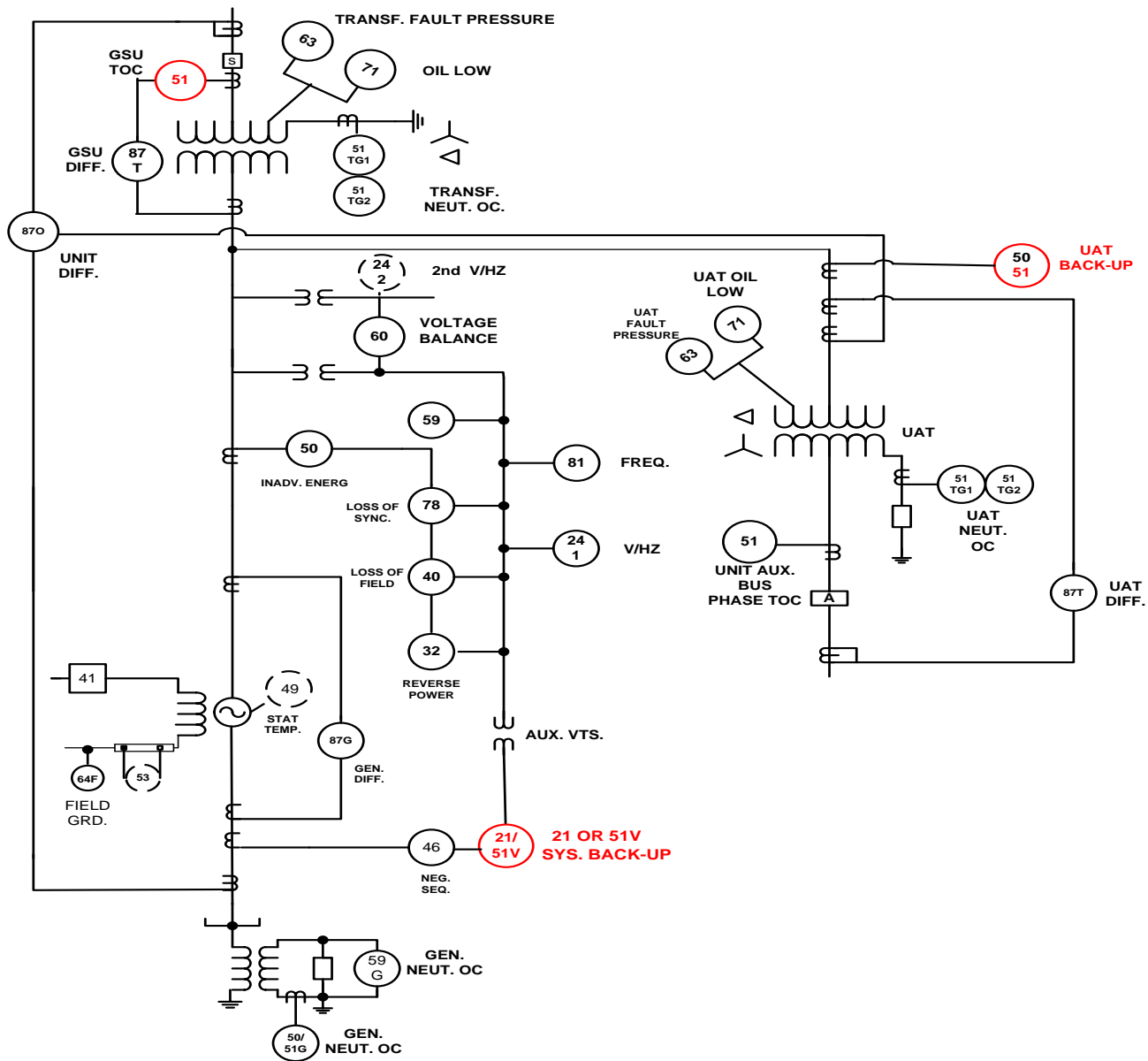


Basic Generator Excitation System NERC Simulation

1.0pu Mw + j [1.5 Mw pu] Mvars

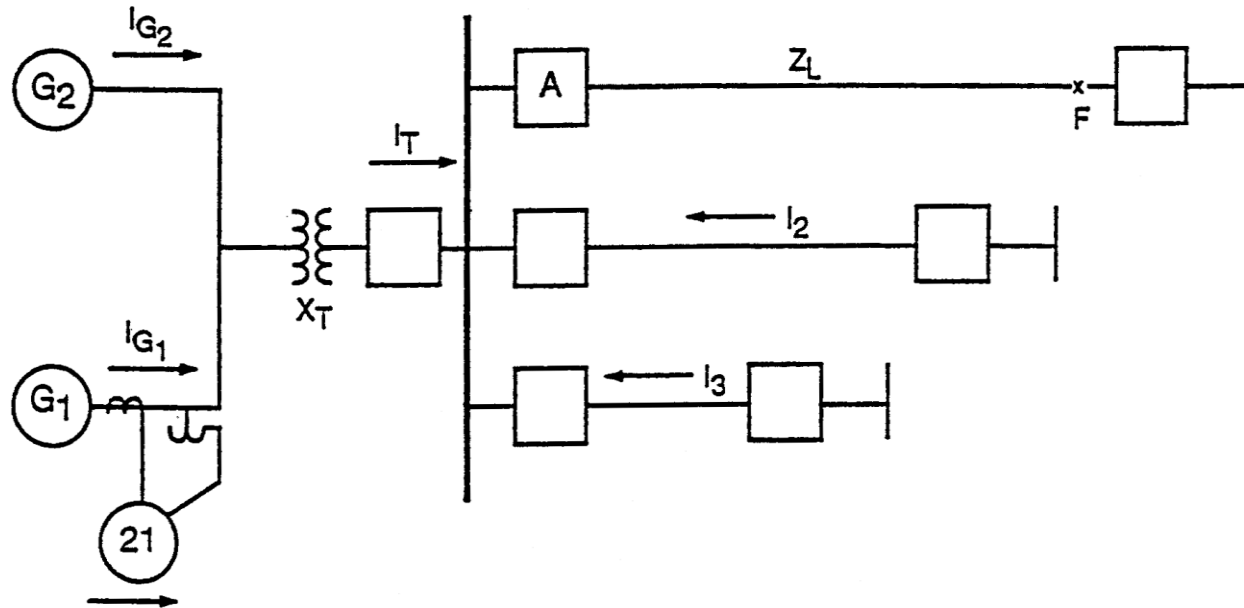


PRC-025-1 Load-Dependent Generator Relays



PHASE DISTANCE IMPEDANCE BACKUP (21)

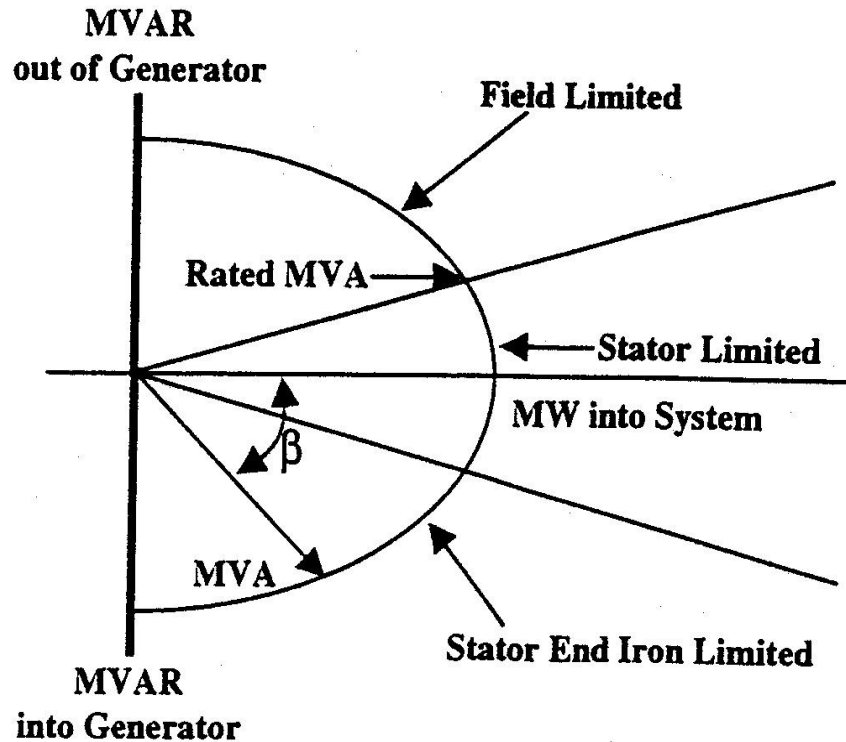
System Phase Fault Backup (21)



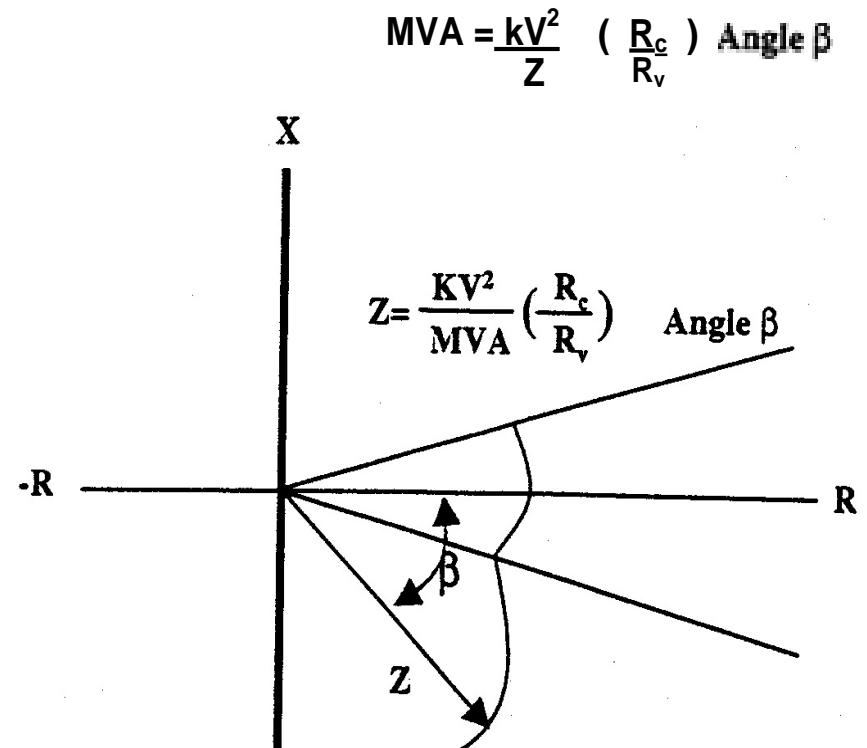
For a fault at F, the approximate apparent impedance effect is:

$$Z_{G1} \approx X_T \frac{[I_{G1} + I_{G2}]}{I_{G1}} + Z_L \left[\frac{I_T + I_2 + I_3}{I_T} \right]$$

Transformation from MW-MVAR to R-X Plot



MW – MVAR

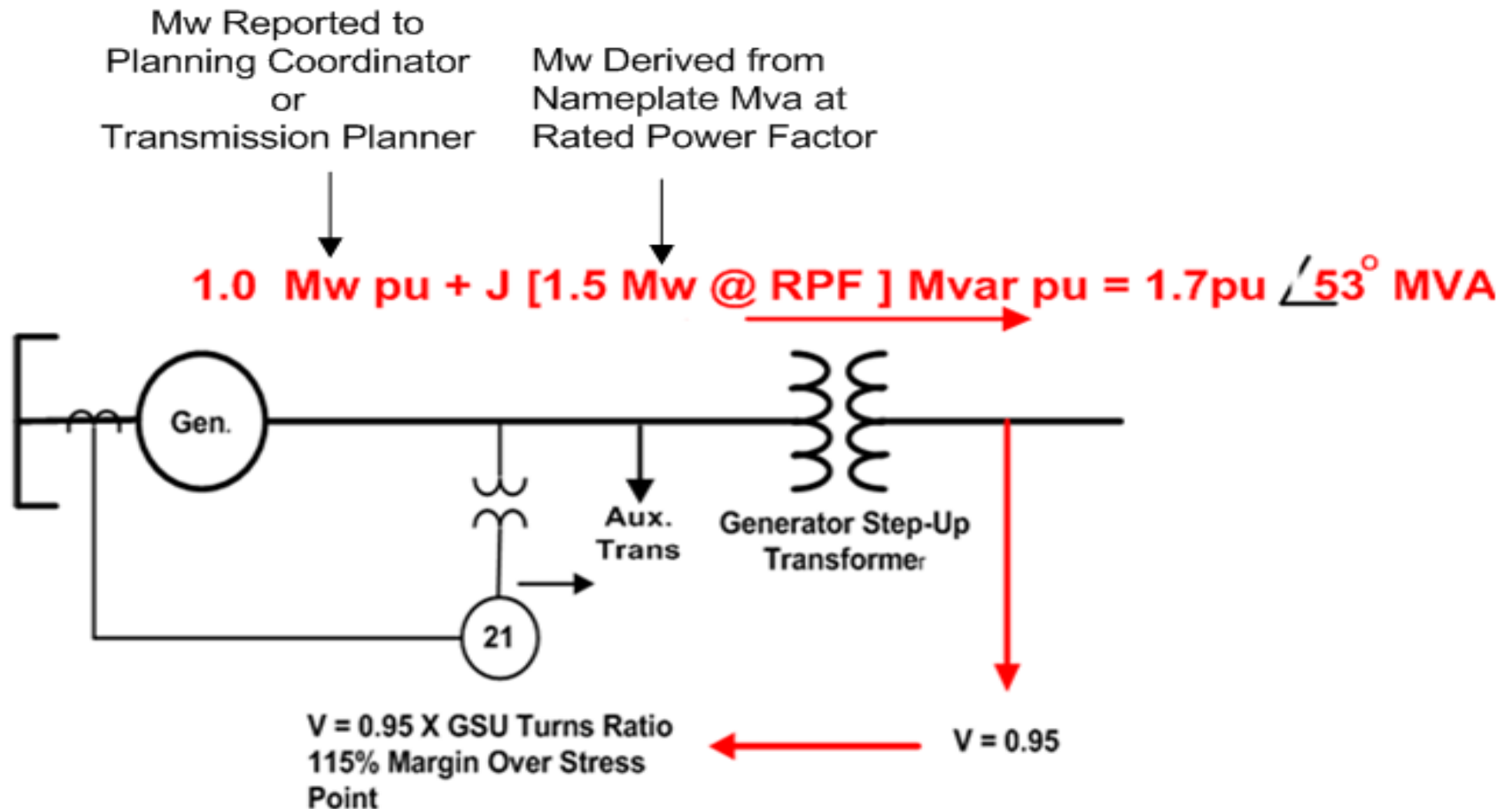


R-X PLOT

Phase Backup (21) Setting Criteria: Options – PRC-025-1

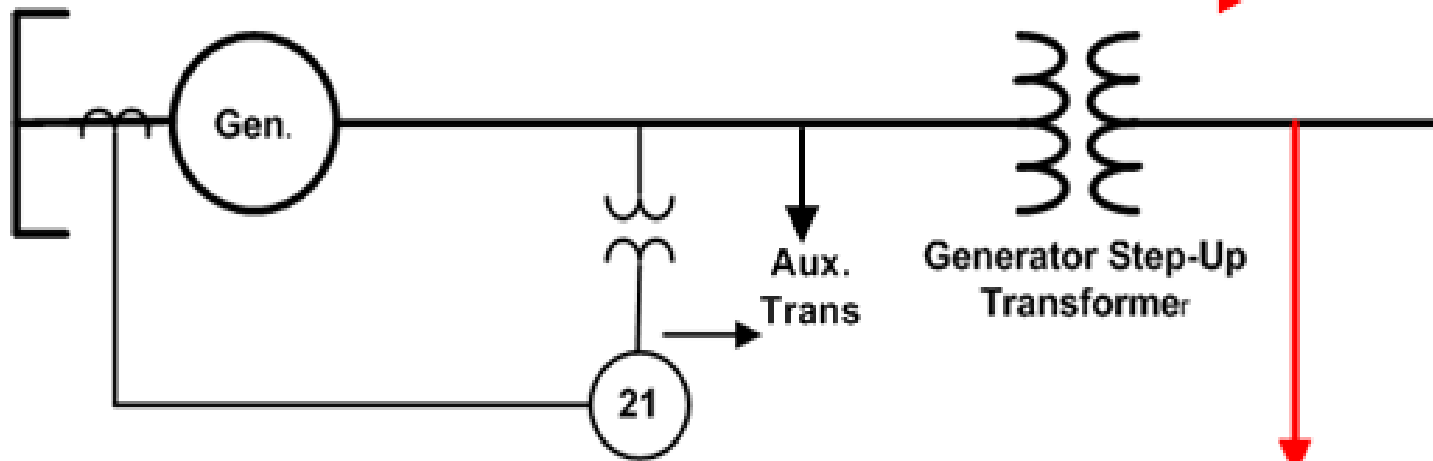
Relay Type	Option	Bus Voltage ³	Pickup Setting Criteria
Phase distance relay (21) – directional toward the Transmission system	1a	Generator bus voltage corresponding to 0.95 per unit of the high-side nominal voltage times the turns ratio of the generator step-up transformer	The impedance element shall be set less than the calculated impedance derived from 115% of: (1) Real Power output – 100% of the MW capability reported to the Planning Coordinator or Transmission Planner, and (2) Reactive Power output – 150% of the MW value, derived from the nameplate MVA rating at rated power factor
	OR		
	1b	Calculated generator bus voltage corresponding to 0.85 per unit nominal voltage on the high-side terminals of the generator step-up transformer (including the transformer turns ratio and impedance)	The impedance element shall be set less than the calculated impedance derived from 115% of: (1) Real Power output – 100% of the MW capability reported to the Planning Coordinator or Transmission Planner, and (2) Reactive Power output – 150% of the MW value, derived from the nameplate MVA rating at rated power factor
	OR		
	1c	Simulated generator bus voltage corresponding to 0.85 per unit nominal voltage on the high-side terminals of the generator step-up transformer (including the transformer turns ratio and impedance)	The impedance element shall be set less than the calculated impedance derived from 115% of: (1) Real Power output – 100% of the MW capability reported to the Planning Coordinator or Transmission Planner, and (2) Reactive Power output – 100% of the maximum gross Mvar output determined by simulation

Phase Backup (21) Setting Criteria: Option #1 – PRC-025-1



Phase Backup (21) Setting Criteria: Option #2 – PRC-025-1

$$1.0 \text{ Mw pu} + j [1.5 \text{ Mw @ RPF}] \text{ Mvar pu} = 1.7 \text{ pu} \angle 53^\circ \text{ MVA}$$



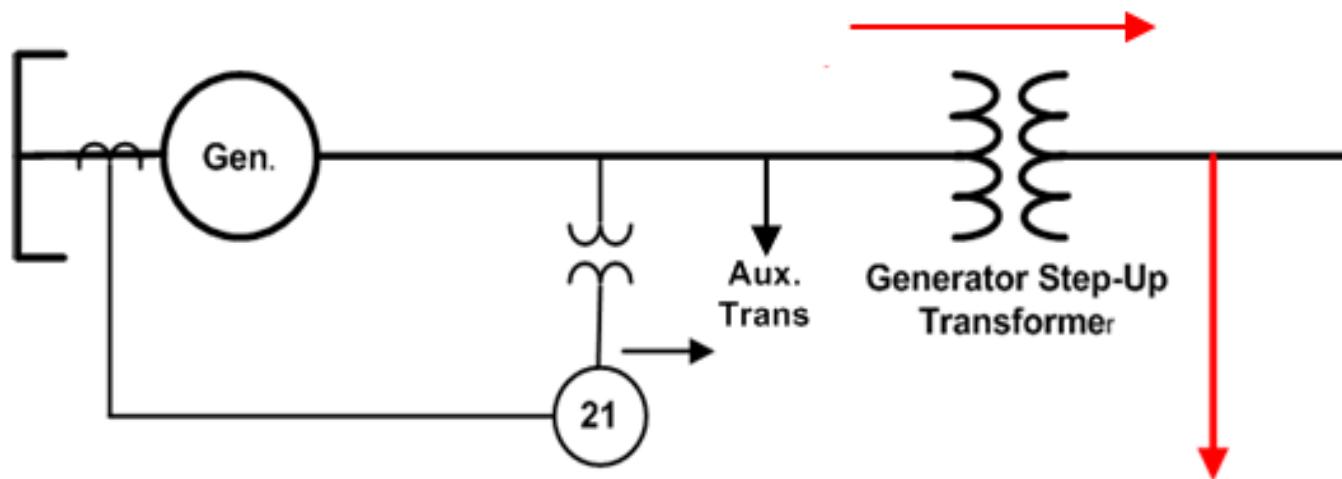
V = Calculate Gen Terminal
Voltage Corresponding to Highside
GSU Voltage = 0.85pu

V = 0.85

115% Margin Over Stress Point

Phase Backup (21) Setting Criteria: Option #3 – PRC-025-1

1.0 pu Mw + J [Determined By Simulation] Mvar = [Sim. Value] MVA



V = Calculate Gen Terminal
Voltage Corresponding to Highside
GSU Voltage = 0.85pu

V = 0.85

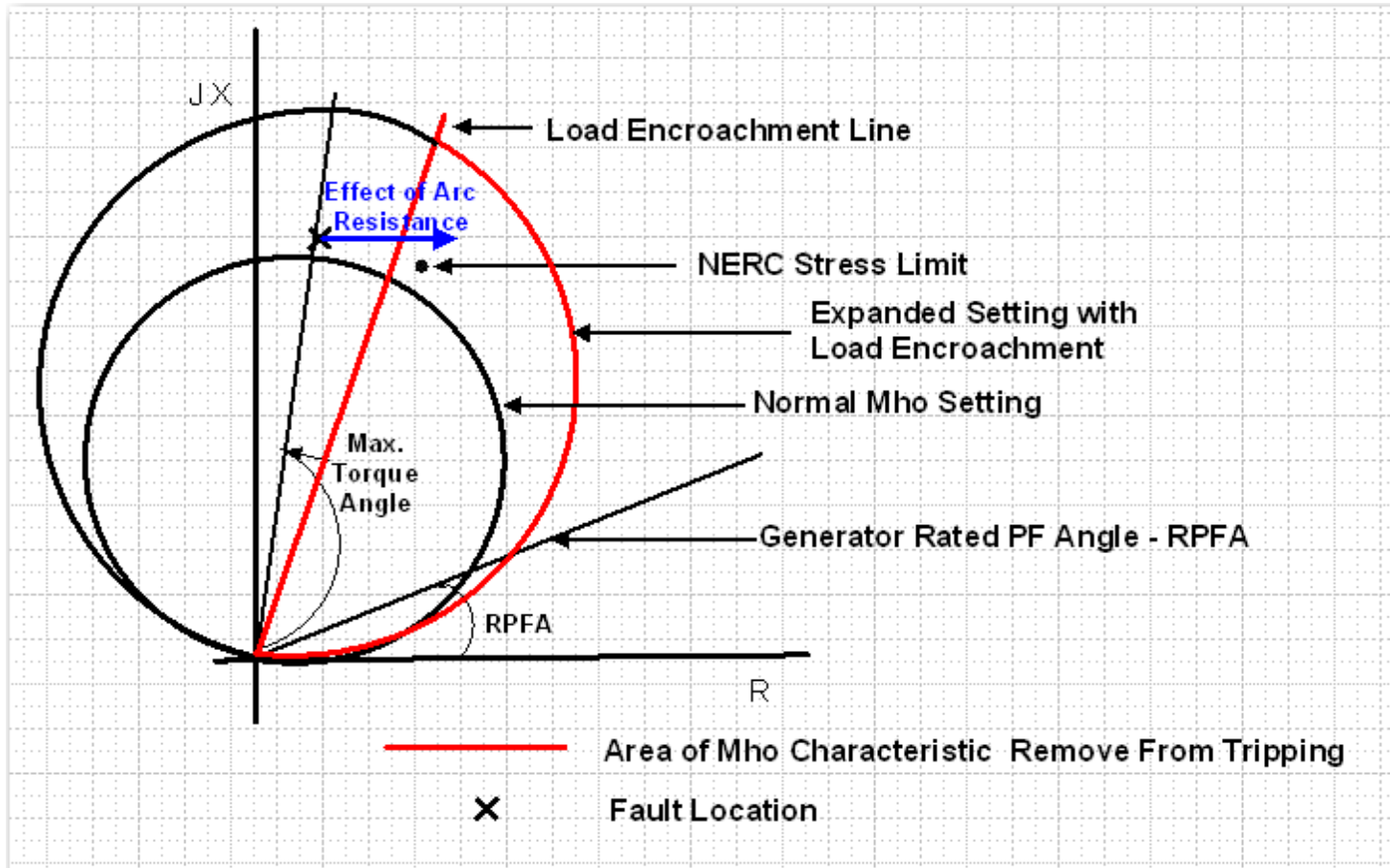
115% Margin Over Stress Point

IS LOAD ENCROACHMENT A GOOD IDEA? SUGGESTED BY PRC-025-1

NERC Test Points

■ NERC Test

1.0pu Mw + j [1.5 Mw pu] Mvars



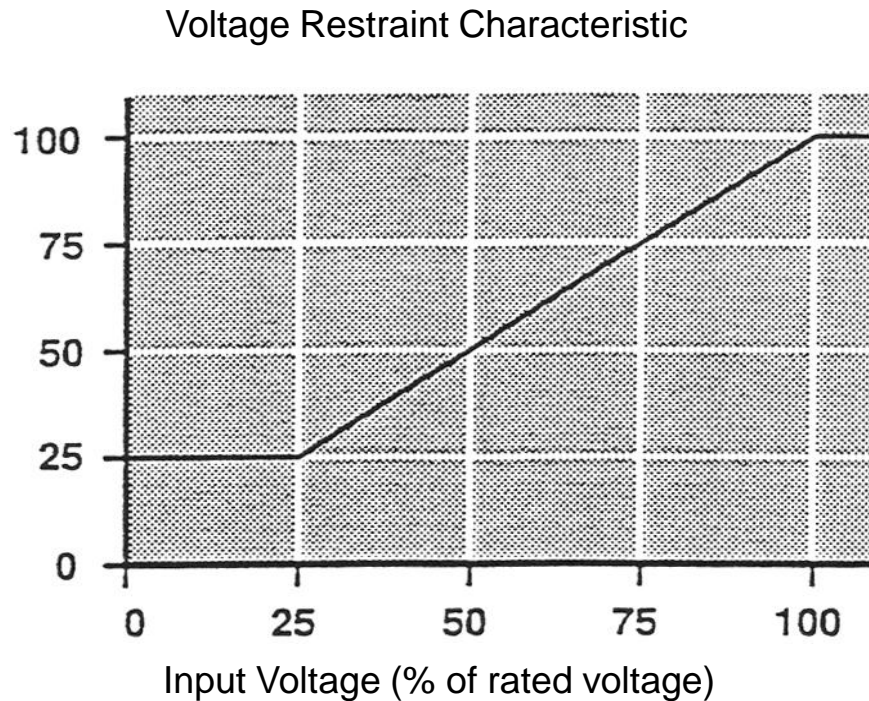
Voltage Control/Restraint Overcurrent (51V)

Voltage Control/Restraint Overcurrent (51V)

- Not as Good as 21 Method of Providing Phase Fault Transmission System Backup
- Difficult to Coordinate with Transmission Line Impedance Relays
- Originally Designed for Industrial System Backup Protection

VOLTAGE RESTRAINT (51VR) CHARACTERISTIC

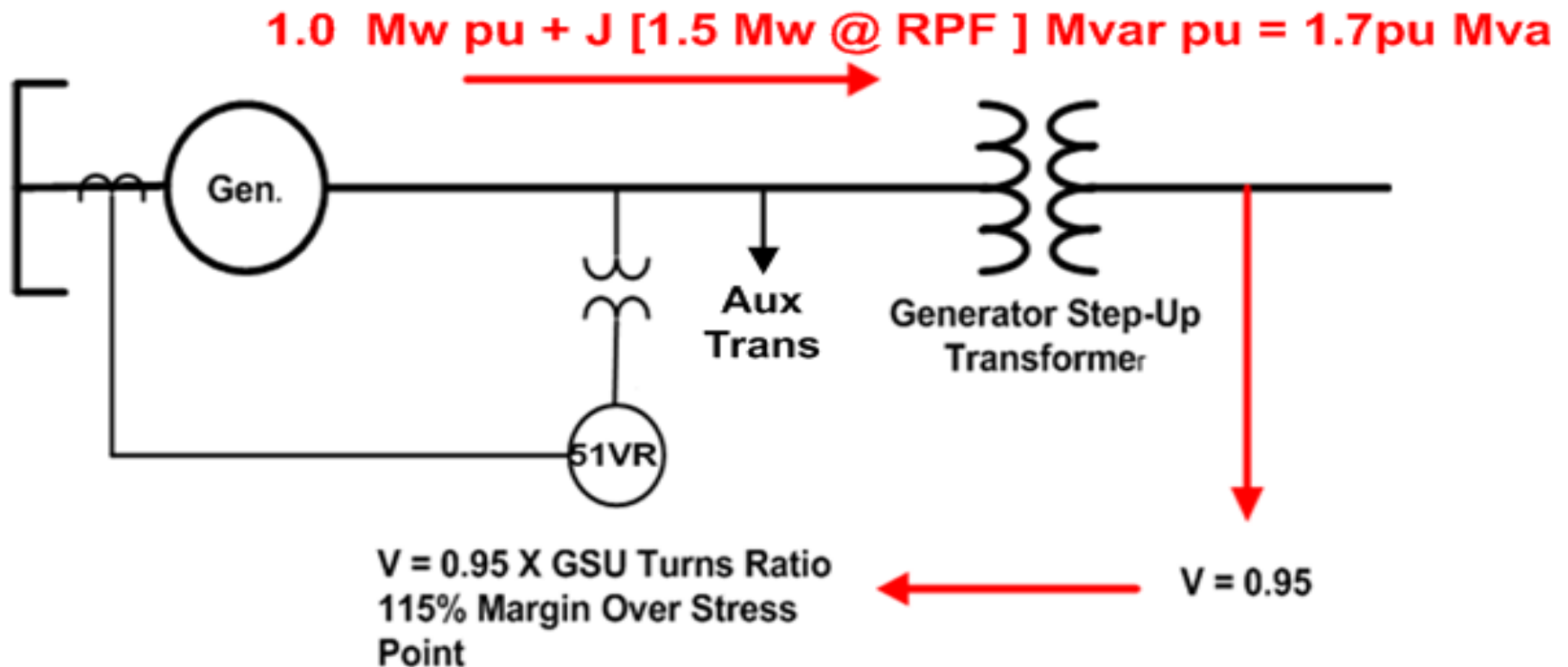
Tap Setting as % of Tap
Setting at Rated
Voltage



PHASE BACKUP (51VR) SETTING CRITERIA: OPTIONS – PRC-025-1

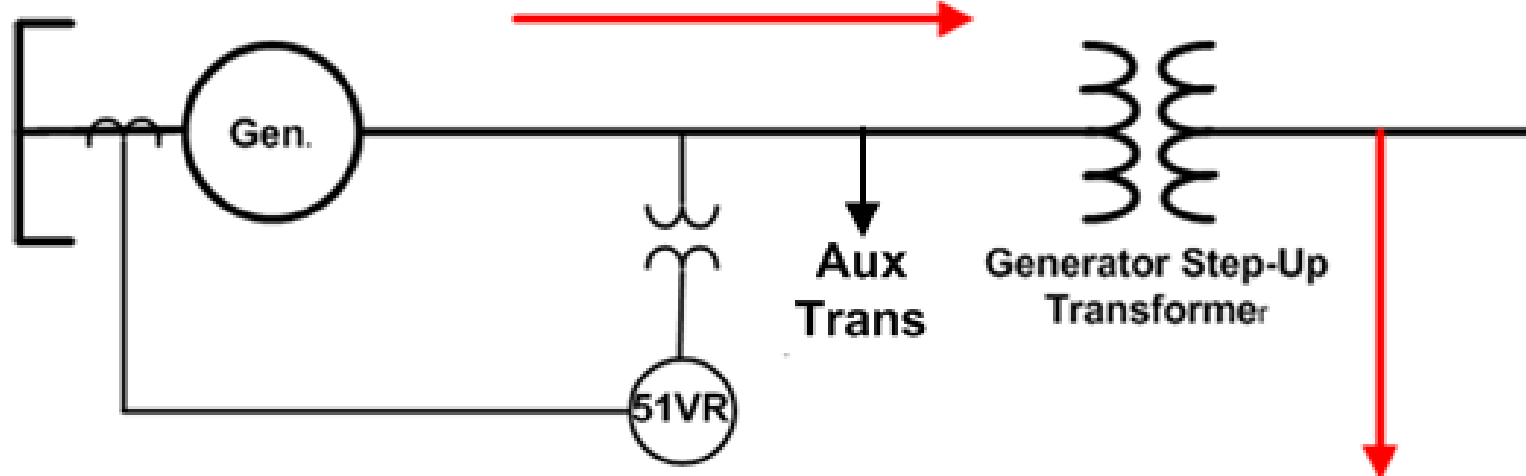
Relay Type	Option	Bus Voltage ³	Pickup Setting Criteria
Phase time overcurrent relay (51V-R) – voltage-restrained	2a	Generator bus voltage corresponding to 0.95 per unit of the high-side nominal voltage times the turns ratio of the generator step-up transformer	<p>The overcurrent element shall be set greater than 115% of the calculated current derived from:</p> <p>(1) Real Power output – 100% of the MW capability reported to the Planning Coordinator or Transmission Planner, and</p> <p>(2) Reactive Power output – 150% of the MW value, derived from the nameplate MVA rating at rated power factor</p>
	OR		
	2b	Calculated generator bus voltage corresponding to 0.85 per unit nominal voltage on the high-side terminals of the generator step-up transformer (including the transformer turns ratio and impedance)	<p>The overcurrent element shall be set greater than 115% of the calculated current derived from:</p> <p>(1) Real Power output – 100% of the MW capability reported to the Planning Coordinator or Transmission Planner, and</p> <p>(2) Reactive Power output – 150% of the MW value, derived from the nameplate MVA rating at rated power factor</p>
	OR		
	2c	Simulated generator bus voltage corresponding to 0.85 per unit nominal voltage on the high-side terminals of the generator step-up transformer (including the transformer turns ratio and impedance)	<p>The overcurrent element shall be set greater than 115% of the calculated current derived from:</p> <p>(1) Real Power output – 100% of the MW capability reported to the Planning Coordinator or Transmission Planner, and</p> <p>(2) Reactive Power output – 100% of the maximum gross Mvar output determined by simulation</p>

PHASE BACKUP (51VR) SETTING CRITERIA: OPTION #1 – PRC-025-1



PHASE BACKUP (51VR) SETTING CRITERIA: OPTION #2 – PRC-025-1

$1.0 \text{ Mw pu} + J [1.5 \text{ Mw @ RPF}] \text{ Mvar pu} = 1.7 \text{ pu Mva}$



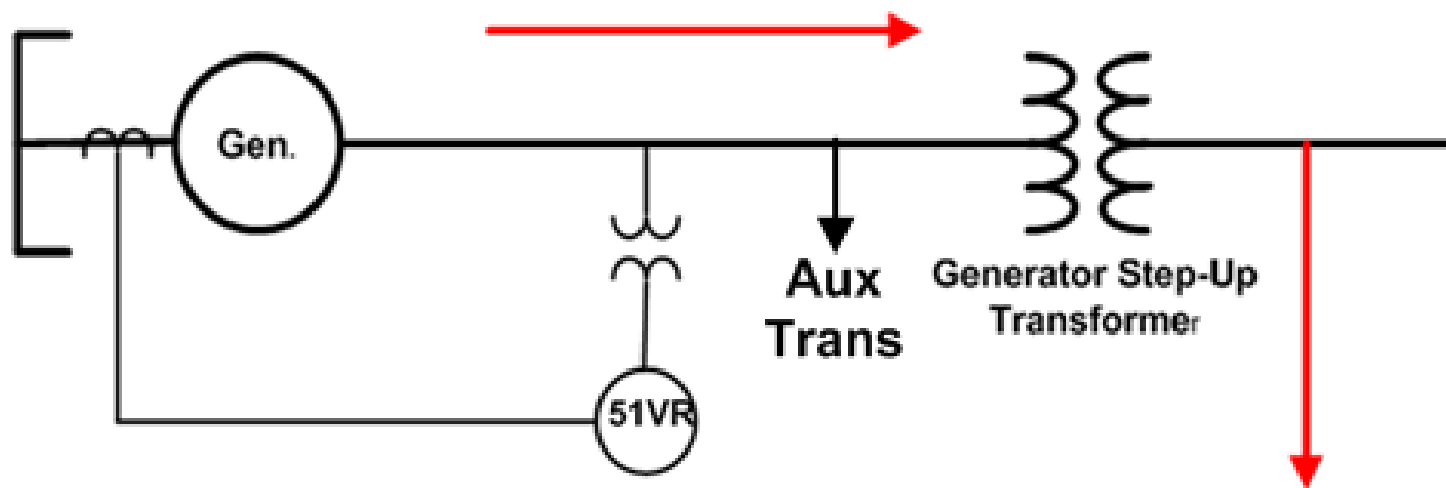
V = Calculate Gen Terminal
Voltage Corresponding to Highside
GSU Voltage = 0.85pu

V = 0.85

115% Margin Over Stress Point

PHASE BACKUP (51VR) SETTING CRITERIA: OPTION #3 – PRC-025-1

1.0pu Mw + j [Determined by Simulation] Mvars = [Calc Value] Mva



V = Calculate Gen Terminal
Voltage Corresponding to Highside
GSU Voltage = 0.85pu

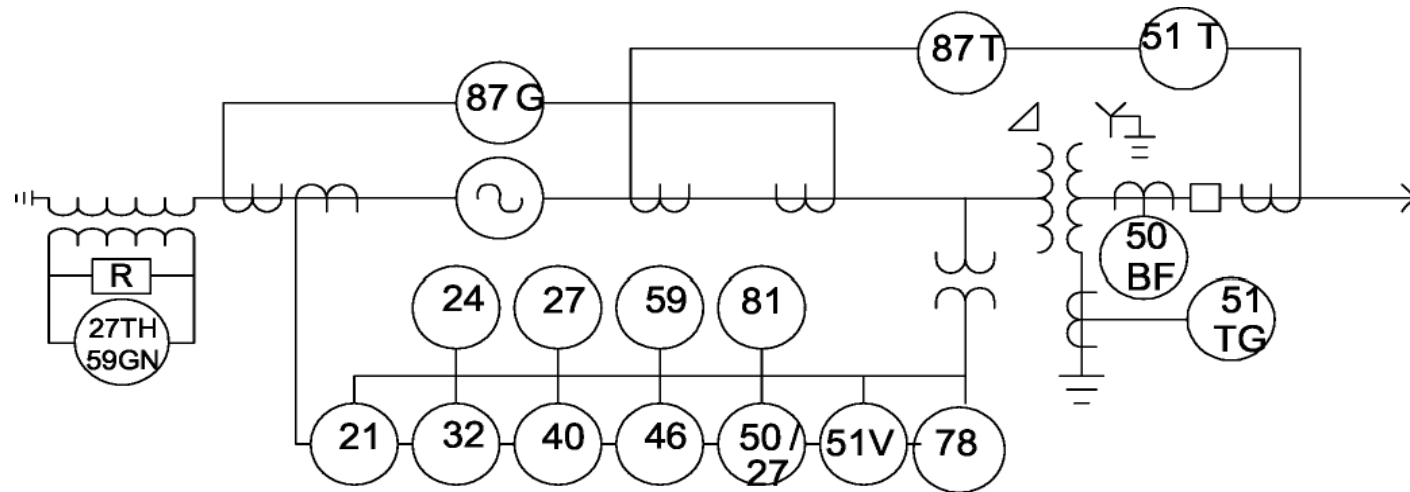
115% Margin Over Stress Point

PHASE BACKUP (51VC) SETTING CRITERIA: OPTIONS – PRC-025-1

Phase time overcurrent relay (51V-C) – voltage controlled (Enabled to operate as a function of voltage)	3	Generator bus voltage corresponding to 1.0 per unit of the high-side nominal voltage times the turns ratio of the generator step-up transformer	Voltage control setting shall be set less than 75% of the calculated generator bus voltage
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GENERATOR STEP-UP TRANSFORMERS (GSU) & AUXILIARY TRANSFORMERS

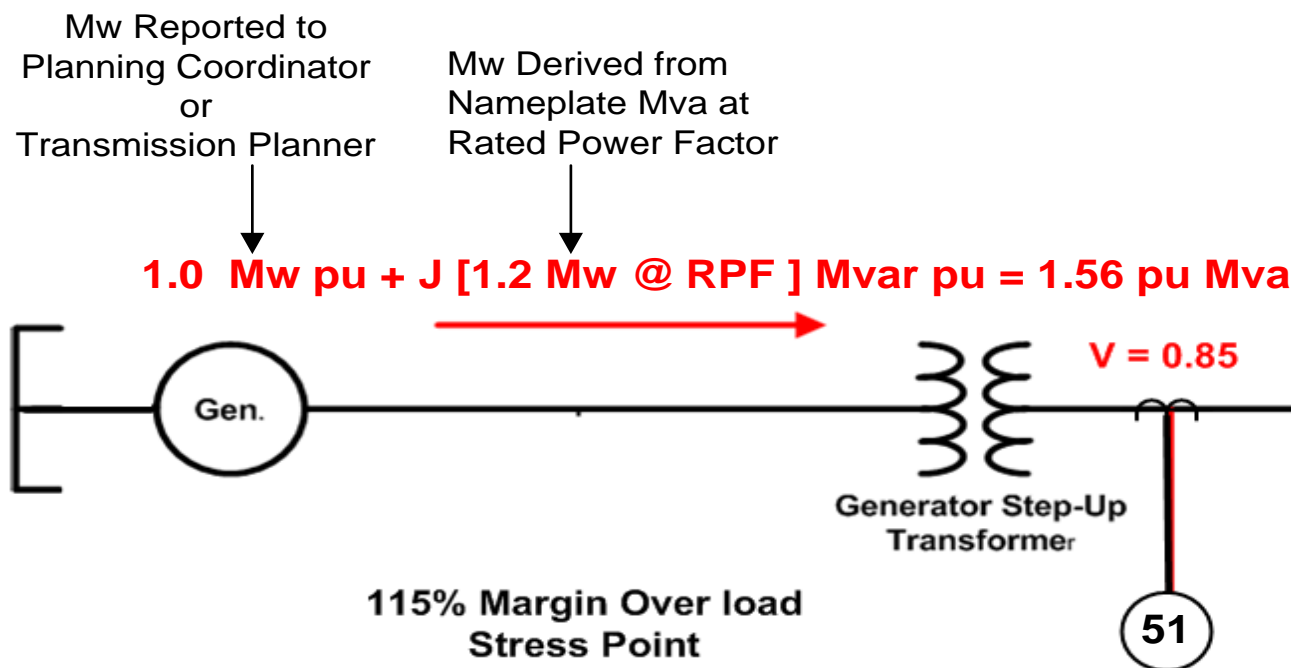
GSU 51T APPLICATION



GSU (51T) SETTING CRITERIA: OPTIONS GSU – PRC-025-2

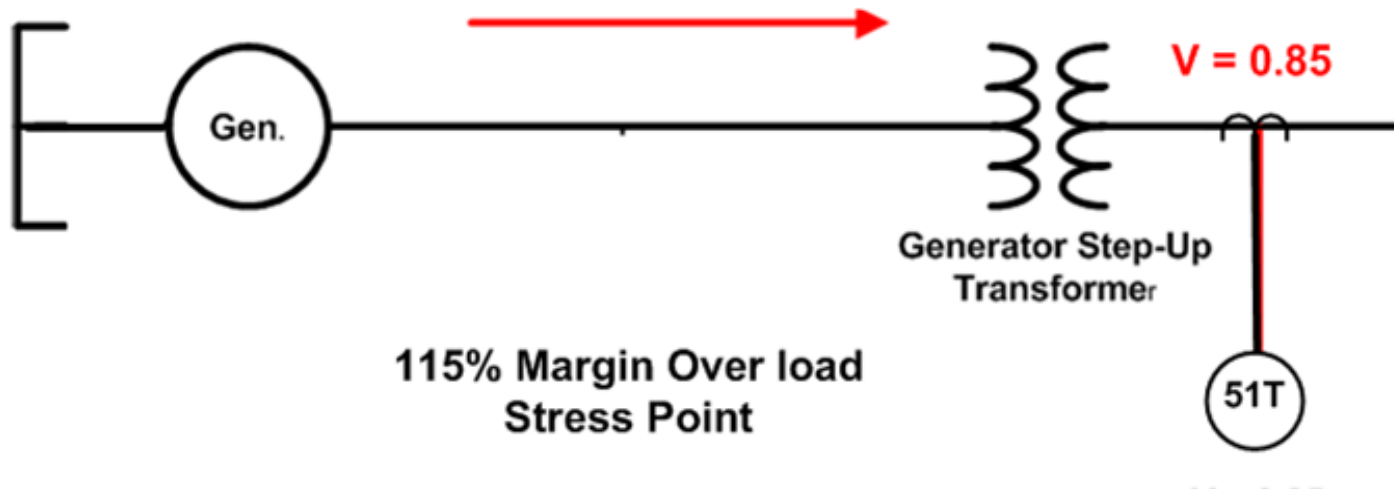
Table 1. Relay Loadability Evaluation Criteria				
Application	Relay Type	Option	Bus Voltage ⁴	Pickup Setting Criteria
Elements that connect the GSU transformer(s) to the Transmission system that are used exclusively to export energy directly from a BES generating unit or generating plant. Elements may also supply generating plant loads. – connected to synchronous generators	Phase overcurrent supervisory element (50) – associated with current-based, communication-assisted schemes where the scheme is capable of tripping for loss of communications installed on the high-side of the GSU transformer or phase time overcurrent relay (51) – installed on the high-side of the GSU transformer	15a	0.85 per unit of the line nominal voltage	The overcurrent element shall be set greater than 115% of the calculated current derived from: (1) Real Power output – 100% of the aggregate generation gross MW reported to the Transmission Planner; and (2) Reactive Power output – 120% of the aggregate generation MW value, derived from the generator nameplate MVA rating at rated power factor
		OR		
		15b	Simulated line voltage coincident with the highest Reactive Power output achieved during field-forcing in response to a 0.85 per unit nominal voltage on the high-side terminals of the generator step-up transformer prior to field-forcing	The overcurrent element shall be set greater than 115% of the calculated current derived from: (1) Real Power output – 100% of the aggregate generation gross MW reported to the Transmission Planner; and (2) Reactive Power output – 100% of the aggregate generation maximum gross Mvar output during field-forcing as determined by simulation
	If the relay is installed on the generator-side of the GSU transformer use Option 8			

GENERATOR STEP-UP 51T TRANSFORMERS OPTION #1 – PRC-025-1

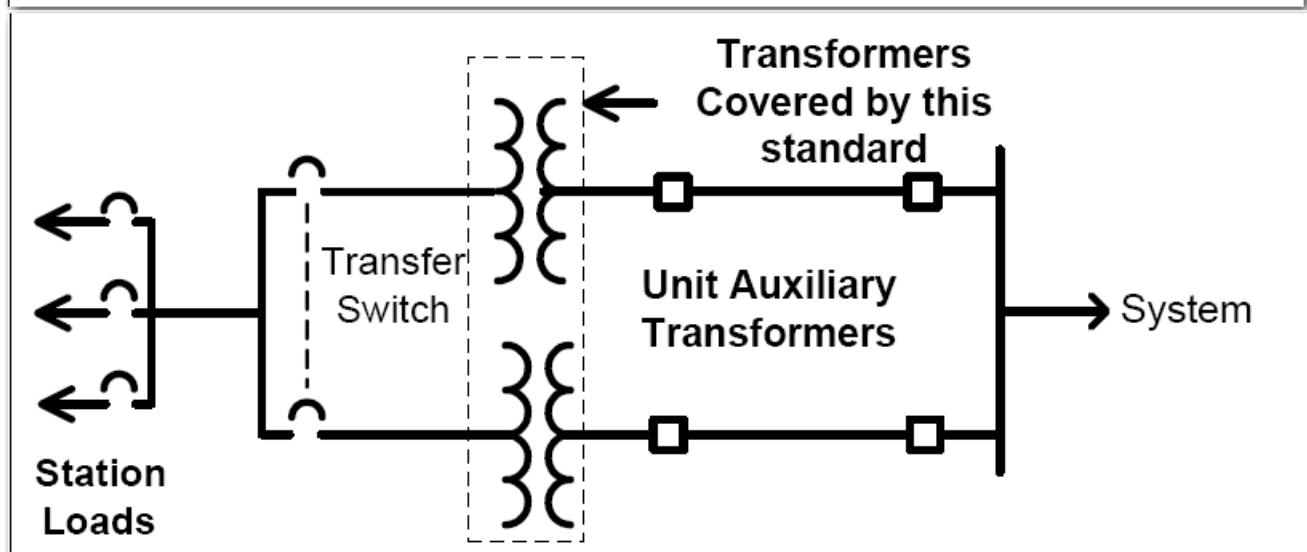
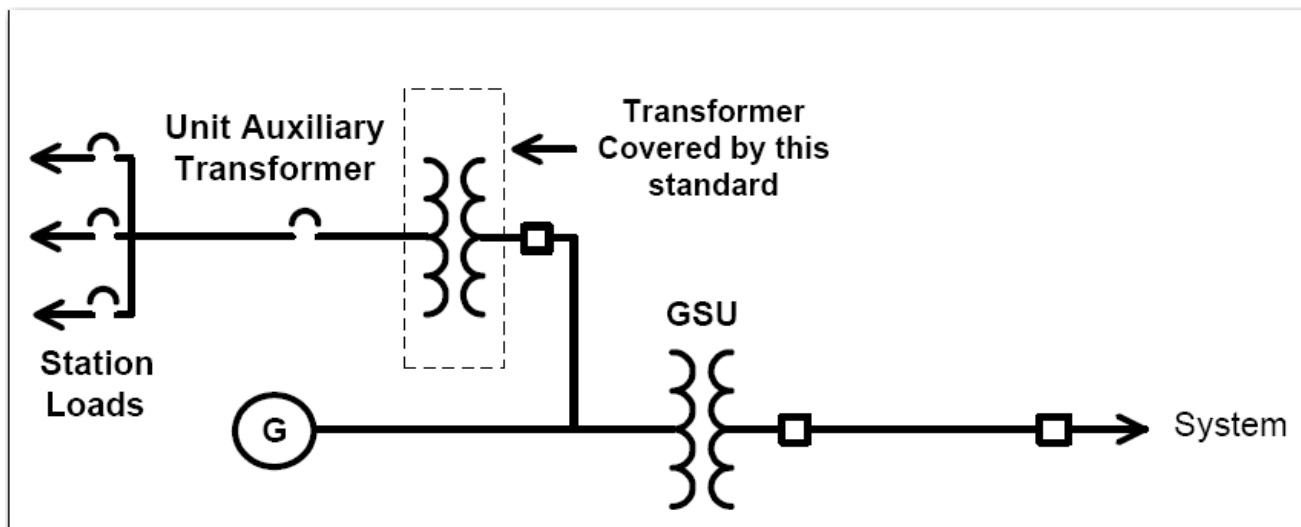


GENERATOR STEP-UP 51T TRANSFORMERS OPTION #2 – PRC-025-1

1.0 Mw + J [Determined by Simultation] Mvar= [Calc. Value] Mva



AUXILIARY TRANSFORMERS COVERED BY – PRC-025-1

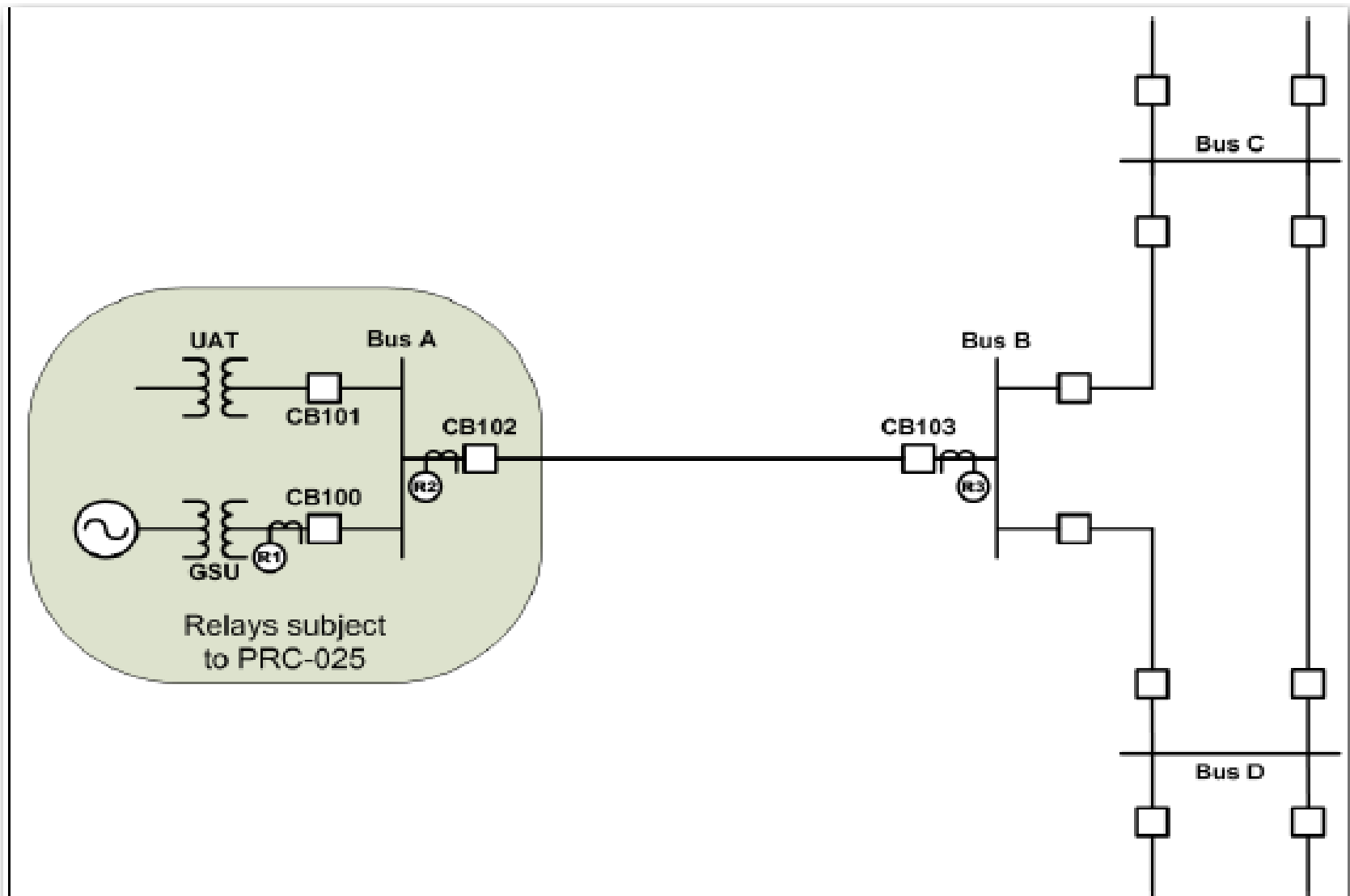


AUXILIARY TRANSFORMERS (51) SETTING CRITERIA: OPTION – PRC-025-1

Application	Relay Type	Option	Bus Voltage ³	Pickup Setting Criteria
Unit auxiliary transformers (UAT)	Phase time overcurrent relay (51)	13a	1.0 per unit of the winding nominal voltage of the unit auxiliary transformer	The overcurrent element shall be set greater than 150% of the calculated current derived from the unit auxiliary transformer maximum nameplate MVA rating
		OR		
		13b	Unit auxiliary transformer bus voltage corresponding to the measured current	The overcurrent element shall be set greater than 150% of the unit auxiliary transformer measured current at the generator maximum gross MW capability reported to the Planning Coordinator or Transmission Planner

POWER PLANT TRANSMISSION LINE BACKUP PROTECTION

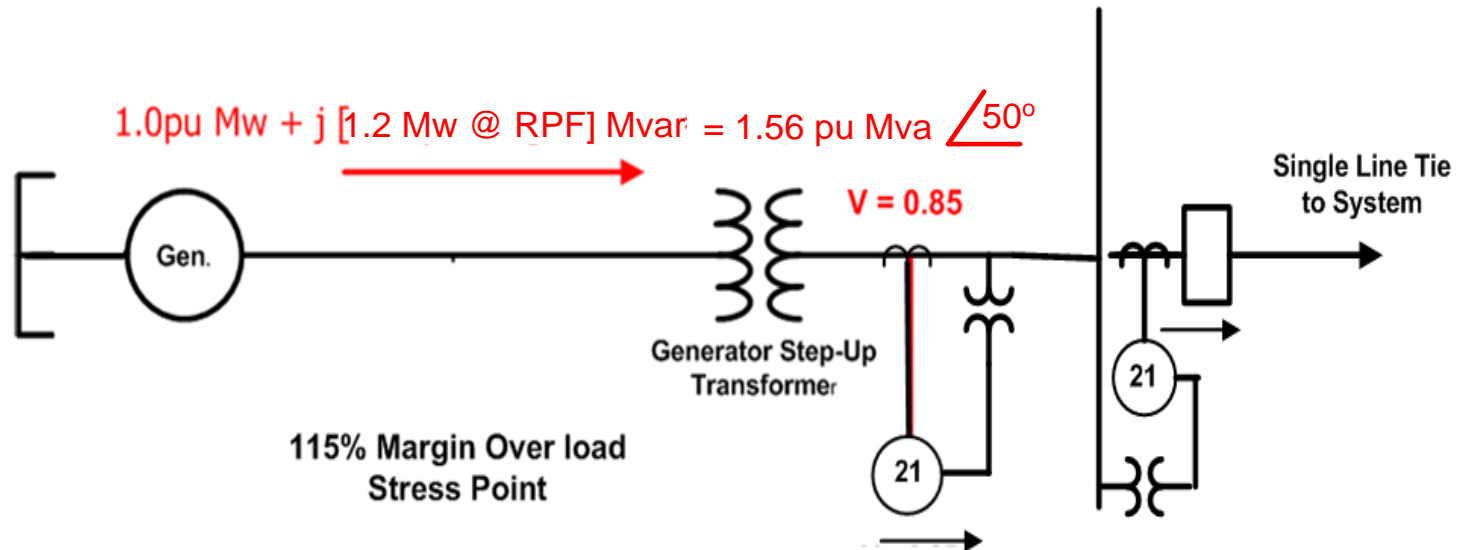
Transmission Line Backup Relays (21)



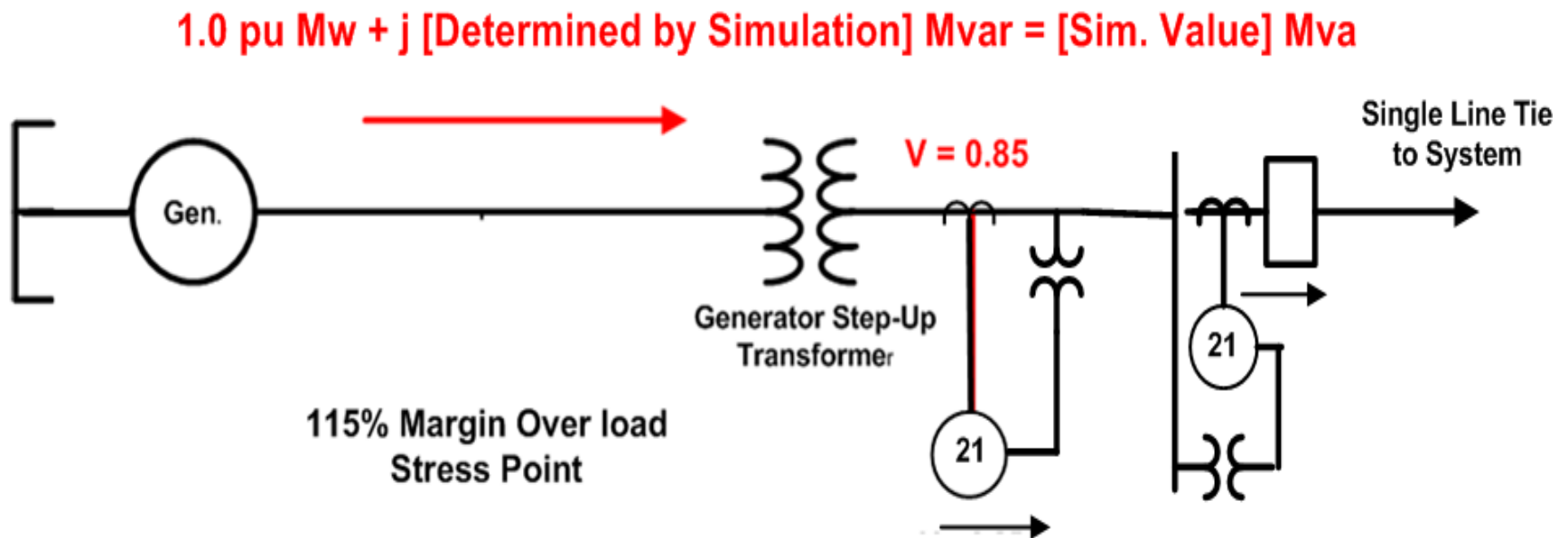
Transmission Line Backup Relays (21)

Table 1. Relay Loadability Evaluation Criteria				
Application	Relay Type	Option	Bus Voltage ⁴	Pickup Setting Criteria
Elements that connect the GSU transformer(s) to the Transmission system that are used exclusively to export energy directly from a BES generating unit or generating plant. Elements may also supply generating plant loads. – connected to synchronous generators	Phase distance relay (21) – directional toward the Transmission system – installed on the high-side of the GSU transformer	14a	0.85 per unit of the line nominal voltage	The impedance element shall be set less than the calculated impedance derived from 115% of: (1) Real Power output – 100% of the aggregate generation gross MW reported to the Transmission Planner; and (2) Reactive Power output – 120% of the aggregate generation MW value, derived from the generator nameplate MVA rating at rated power factor
		OR		
	If the relay is installed on the generator-side of the GSU transformer use Option 7	14b	Simulated line voltage coincident with the highest Reactive Power output achieved during field-forcing in response to a 0.85 per unit nominal voltage on the high-side terminals of the generator step-up transformer prior to field-forcing	The impedance element shall be set less than the calculated impedance derived from 115% of: (1) Real Power output – 100% of the aggregate generation gross MW reported to the Transmission Planner; and (2) Reactive Power output – 100% of the aggregate generation maximum gross Mvar output during field-forcing as determined by simulation

TRANSMISSION LINE BACKUP (21) SETTING CRITERIA: OPTION #1 – PRC-025-1



TRANSMISSION LINE BACKUP (21) SETTING CRITERIA: OPTION #2 – PRC-025-1



Conclusions

- As a Result of NERC Analysis of 2003 Blackout Data, NERC has Proposed “Voltage Ride-Through” Criteria.
- The “Voltage Ride-Through” Setting Options are Outlined in Guidelines for Load Responsive Relays (PRC-025-1).
- Result in Very Limited Remote Backup by Generator 21 and 51V relays.
- May Require Upgrade of Transmission Line Protection for Lines Exiting Power Plants.

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Questions?