DER inverter control fault ride through model in accordance with IEEE 1547-2018 Std.

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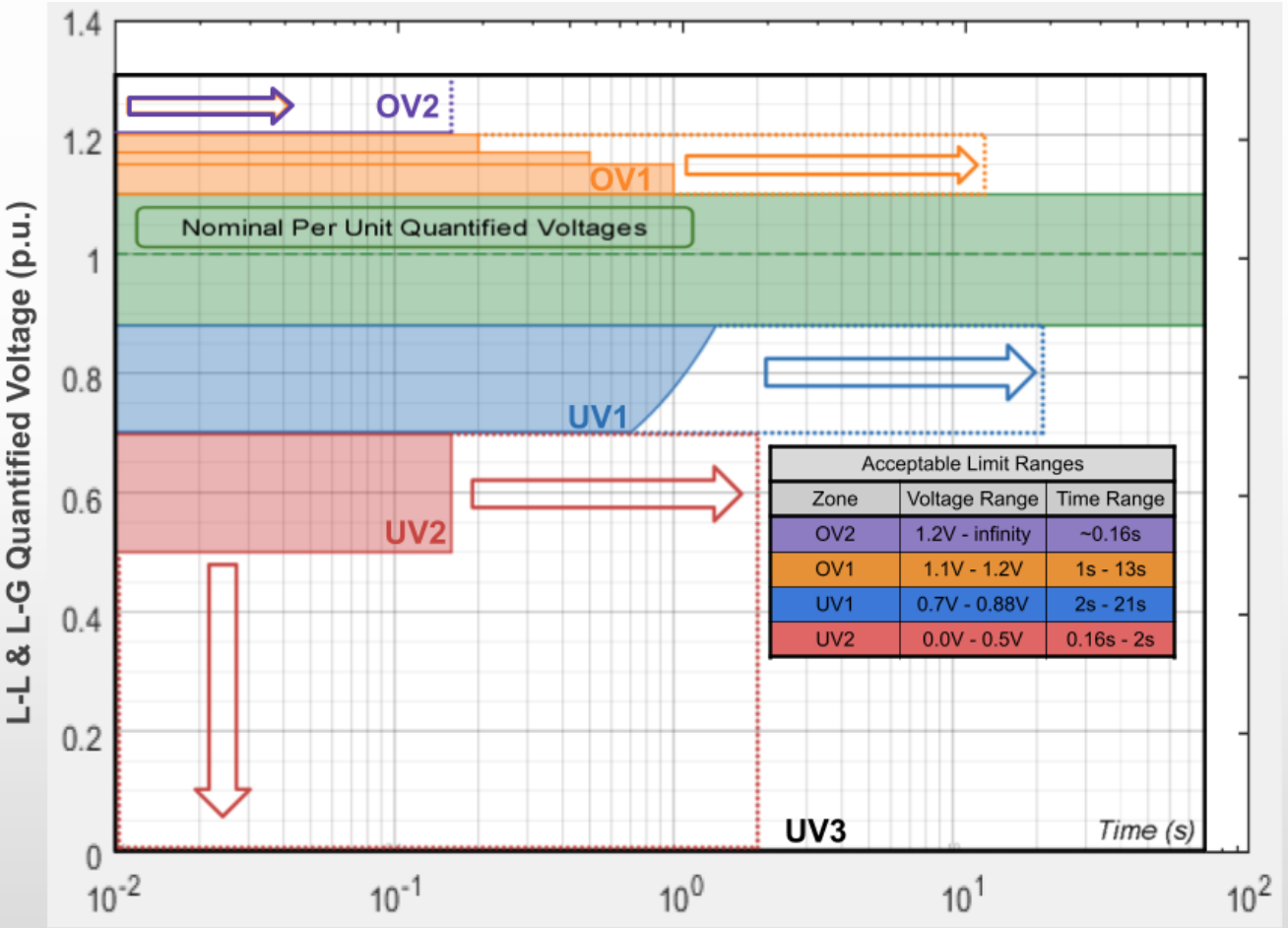
Introduction

Equip Distributed Energy Resource (DER) windfarm to comply with IEEE Std. 1547-2018, High Voltage Ride Through (HVRT) and Low Voltage Ride Through (LVRT)

1. IEEE Std. 1547-2018 Background
2. Reconstruct RMS meter
3. Base Model Background
4. Implement Sensing and Timing Control Logic
5. Implement Breaker Control
6. Results of Under and Over Voltages
7. Future Work
8. Questions and Answers

IEEE Std. 1547-2018 HVRT & LVRT

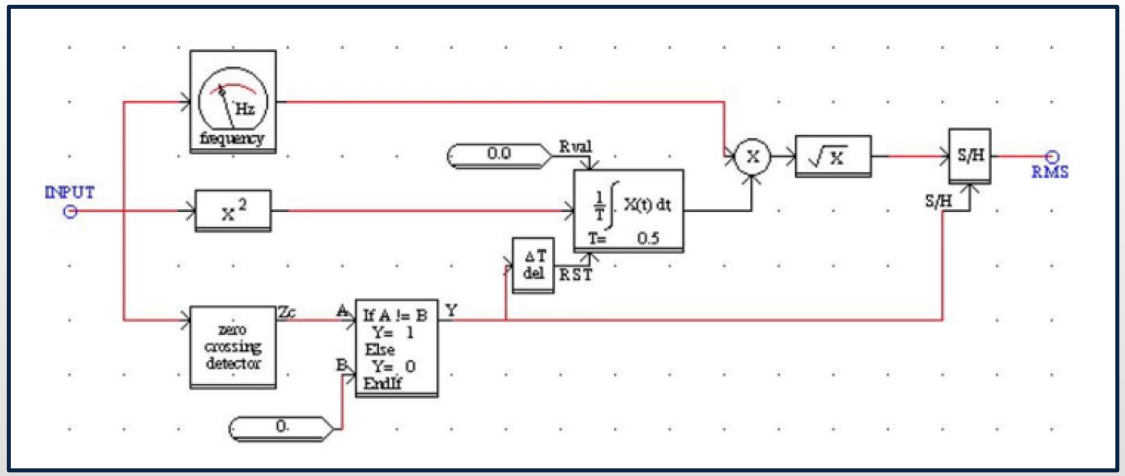
- Defines the conditions where DER should cease to energize the grid for category 1
- Assigns Applicable Voltages based on grid voltage and phase layout
- Specifies undervoltage and overvoltage zones
- Allows operators to adjust trip zones based on DER needs

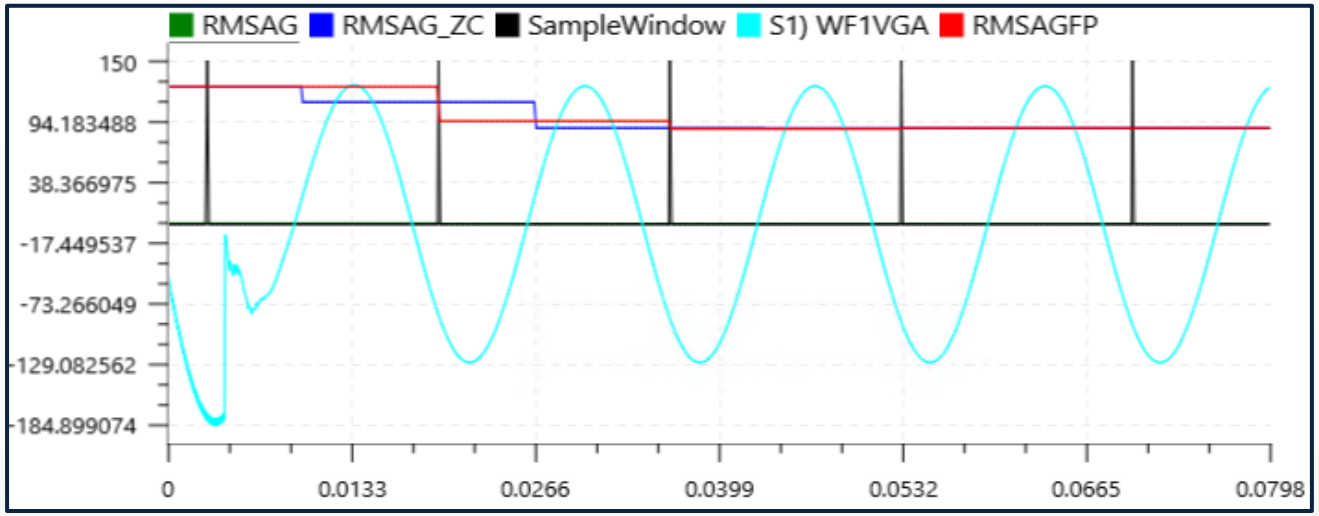


RMS Measurement

RSCAD Library RMS Meter:

- Samples RMS every zero crossing
- Fault transients may trigger RMS update



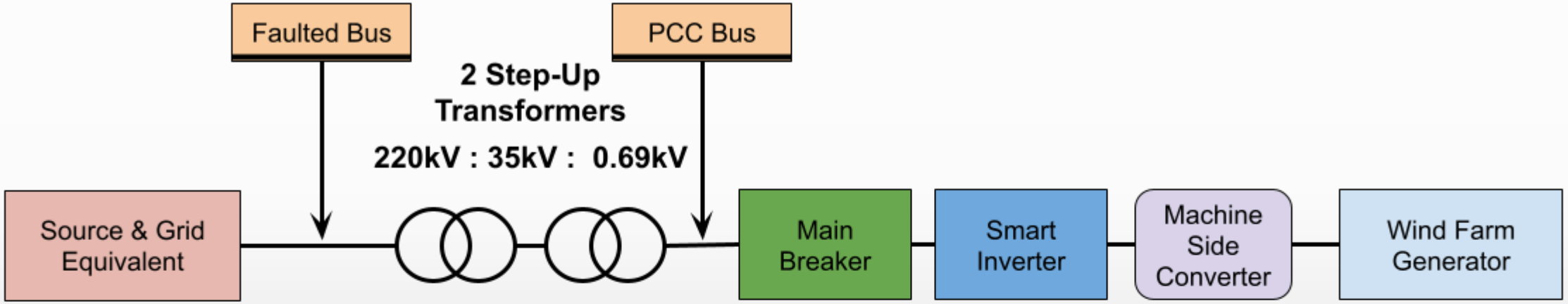


Standard's Metering Requirement:

- Samples RMS in full period intervals

Model Background

PMSM LVRT/HVRT Grid-linked Smart Inverter



Thevenin Equivalent Grid

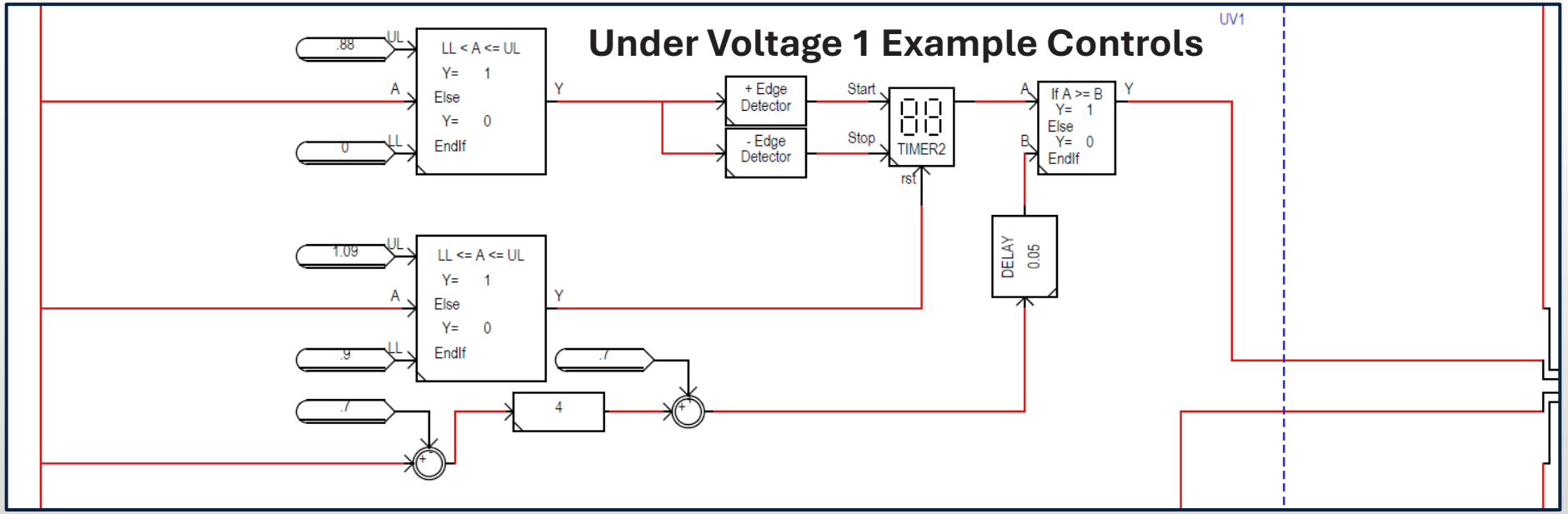
Supplies Grid with Transmission Level Voltages

Utilizes Smart Inverter Grid Support Functions

Ride-Through Control Logic

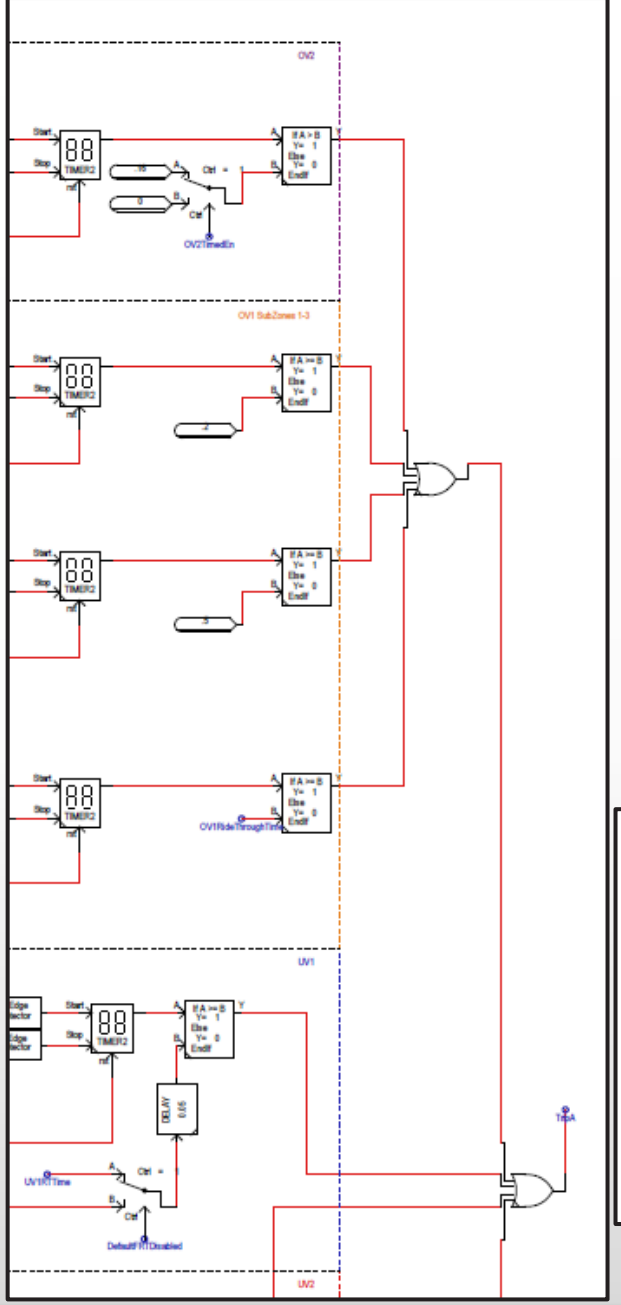
- "Range Check" component senses voltage zone.
- High output starts the timer
- Low output stops the timer
- "Signal Comparator" component checks whether ride through time has been exceeded
- Timer resets when voltage returns to nominal

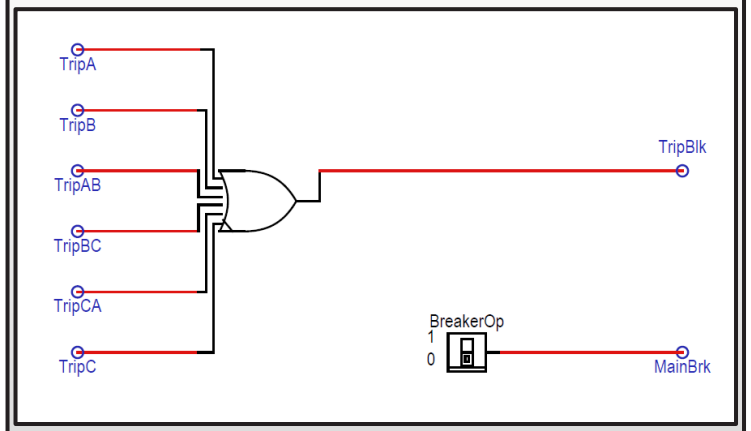
$$T_{VRT} = 0.7\ \text{s} + \frac{4\ \text{s}}{1\ \text{p.u.}}(V - 0.7\ \text{p.u.})$$

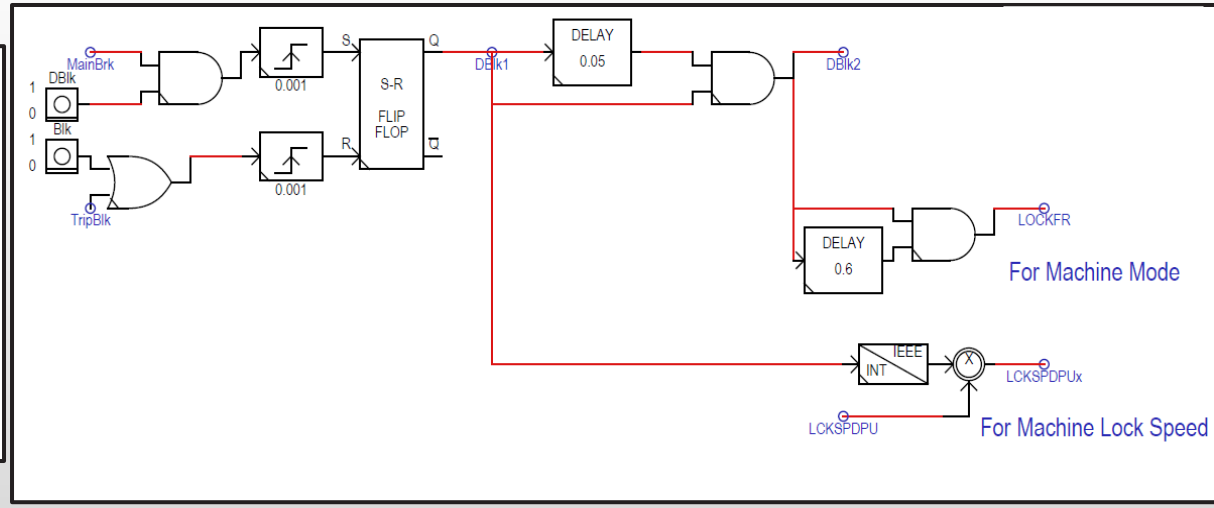


Tripping Control Logic

- Routes through “OR” gates
- Connects to inverter blocking control scheme
- Implemented breaker open & close switch





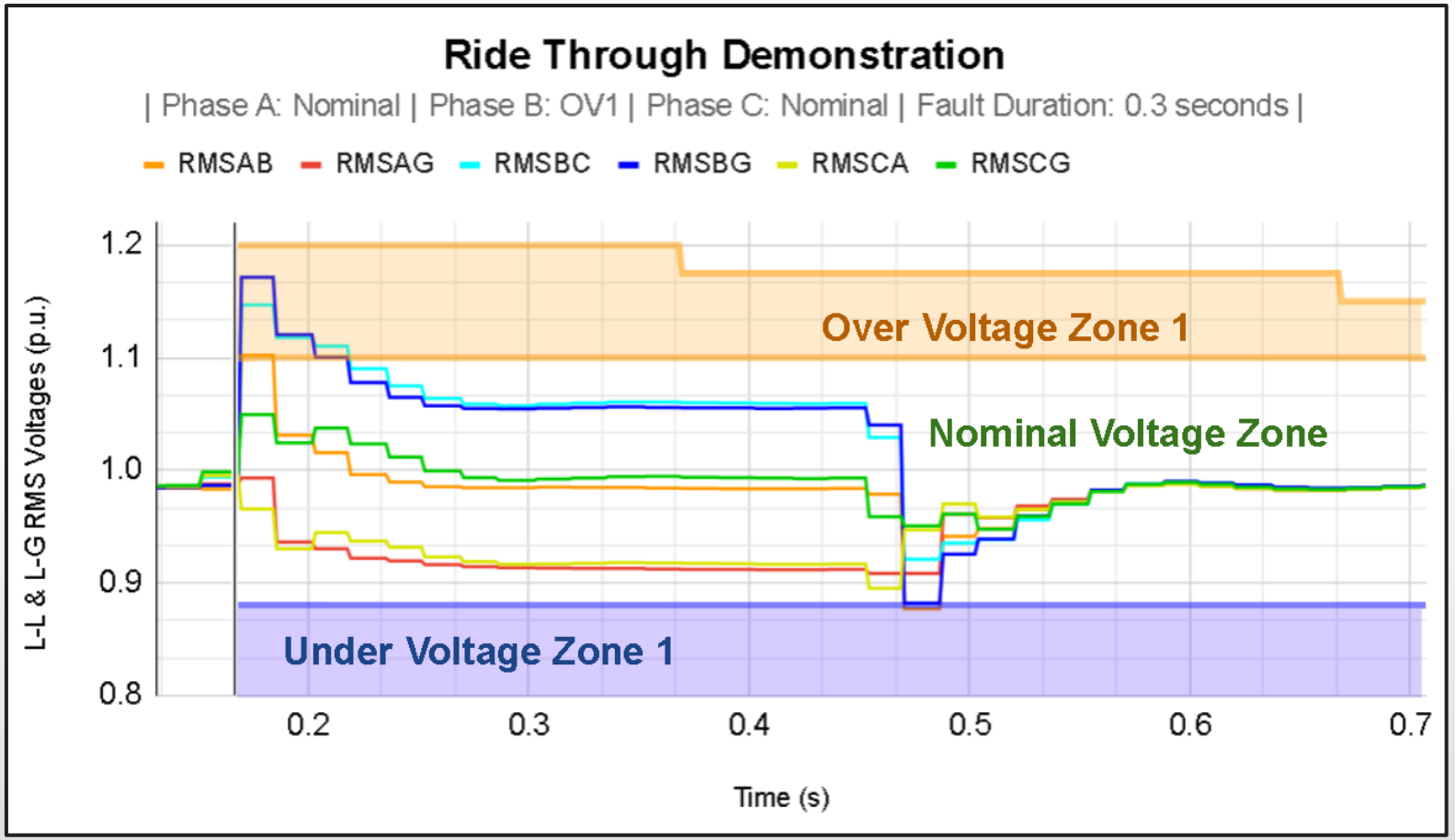


Control Summary

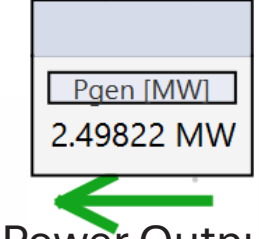
Voltage range (p.u.)	Operating mode/response	Minimum ride-through time (s) (design criteria)	Maximum response time (s) (design criteria)
$V > 1.20$	Cease to Energize[a]	N/A	0.16
$1.175 < V \leq 1.20$	Permissive Operation	0.2	N/A
$1.15 < V \leq 1.175$	Permissive Operation	0.5	N/A
$1.10 < V \leq 1.15$	Permissive Operation	1	N/A
$0.88 \leq V \leq 1.10$	Continuous Operation	Infinite	N/A
$0.70 \leq V < 0.88$	Mandatory Operation	Linear slope of 4 s/1 p.u. voltage starting at 0.7 s @ 0.7 p.u.: $T_{VRT} = 0.7\ \text{s} + \frac{4\ \text{s}}{1\ \text{p.u.}}(V - 0.7\ \text{p.u.})$	N/A
$0.50 \leq V < 0.70$	Permissive Operation	0.16	N/A
$V < 0.50$	Cease to Energize[a]	N/A	0.16

Demonstration Ride -Through

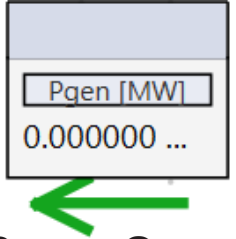
- Voltages per unit quantity manually set
- Grid support functions allow ride-through
- RMS voltages reach zones **OV1** & **UV1**



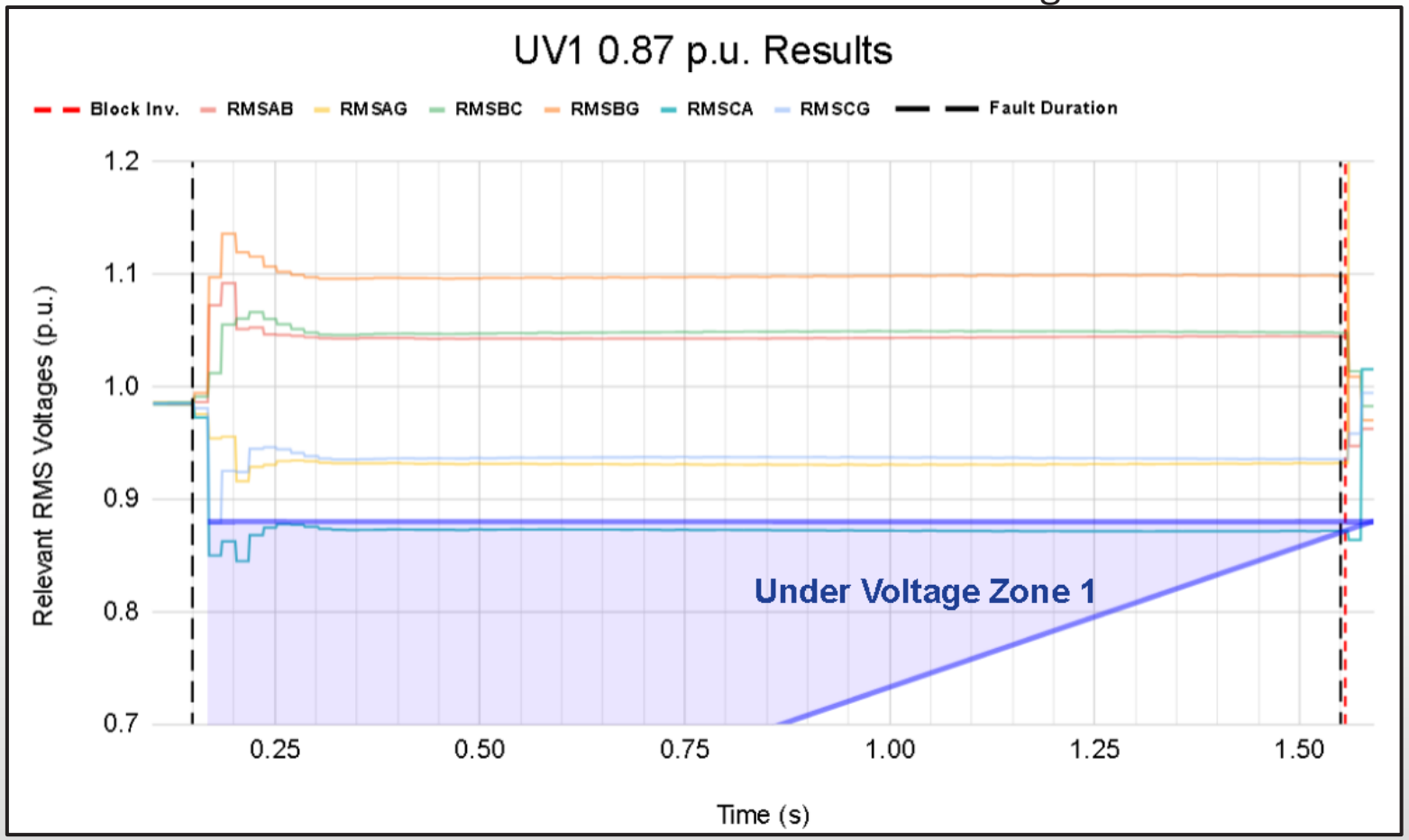
Demonstration
UV1 Trip



Power Output
Before Blocking



Power Output
After Blocking



- Phase A to ground 1.5s fault
- RMS L-L Voltage A-B is 0.87 p.u.
- Cease to energize in 1.38s
- 1.38s > 1.5s: Block Inverter

$$T_{VRT} = 0.7\ \text{s} + \frac{4\ \text{s}}{1\ \text{p.u.}}(V - 0.7\ \text{p.u.})$$

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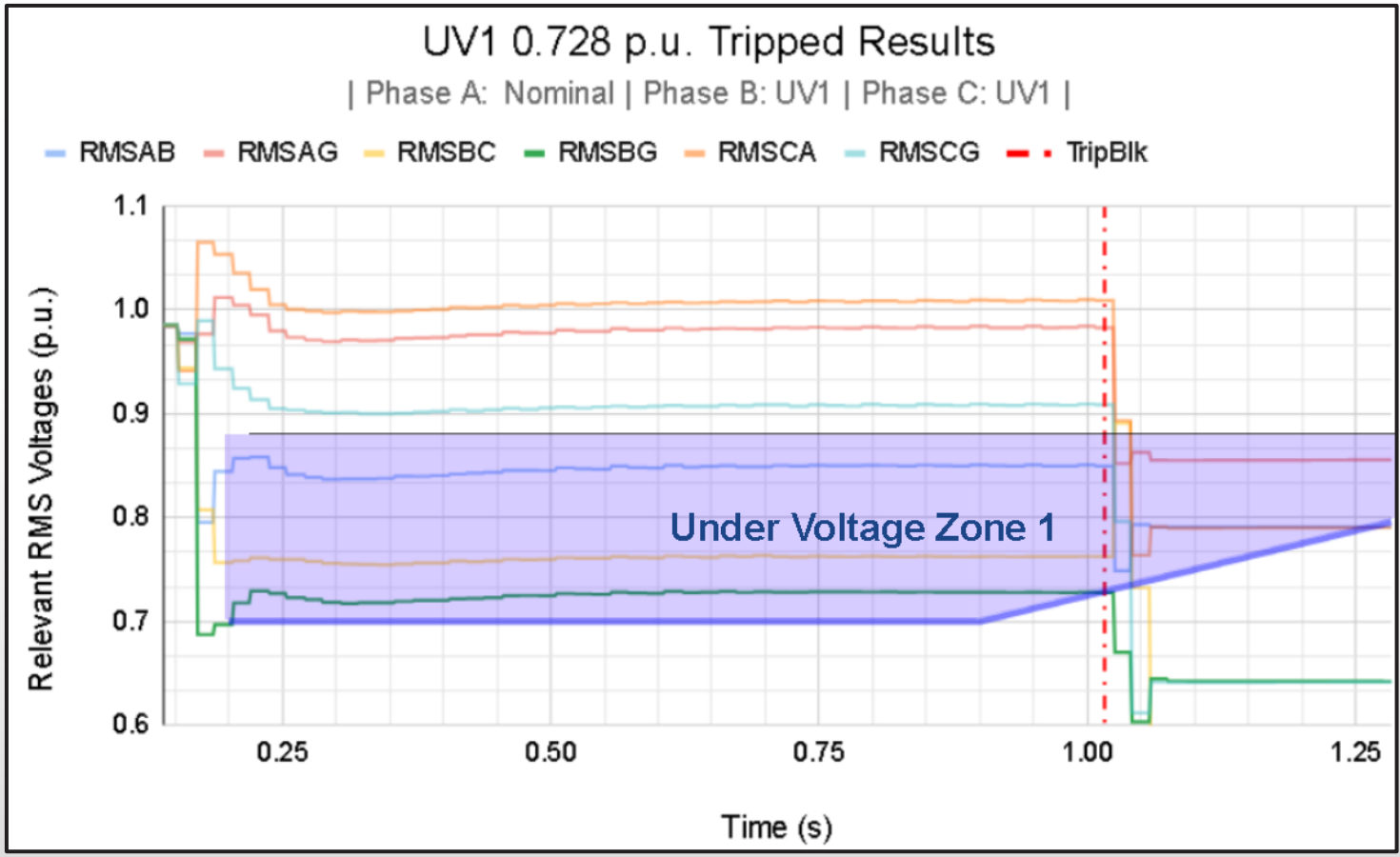
Demonstration UV1 Ride -Through

- Simulating a two phase to ground fault
- Lowest Signal is L-L RMS Voltage B-C
- Rides-Through for 812ms

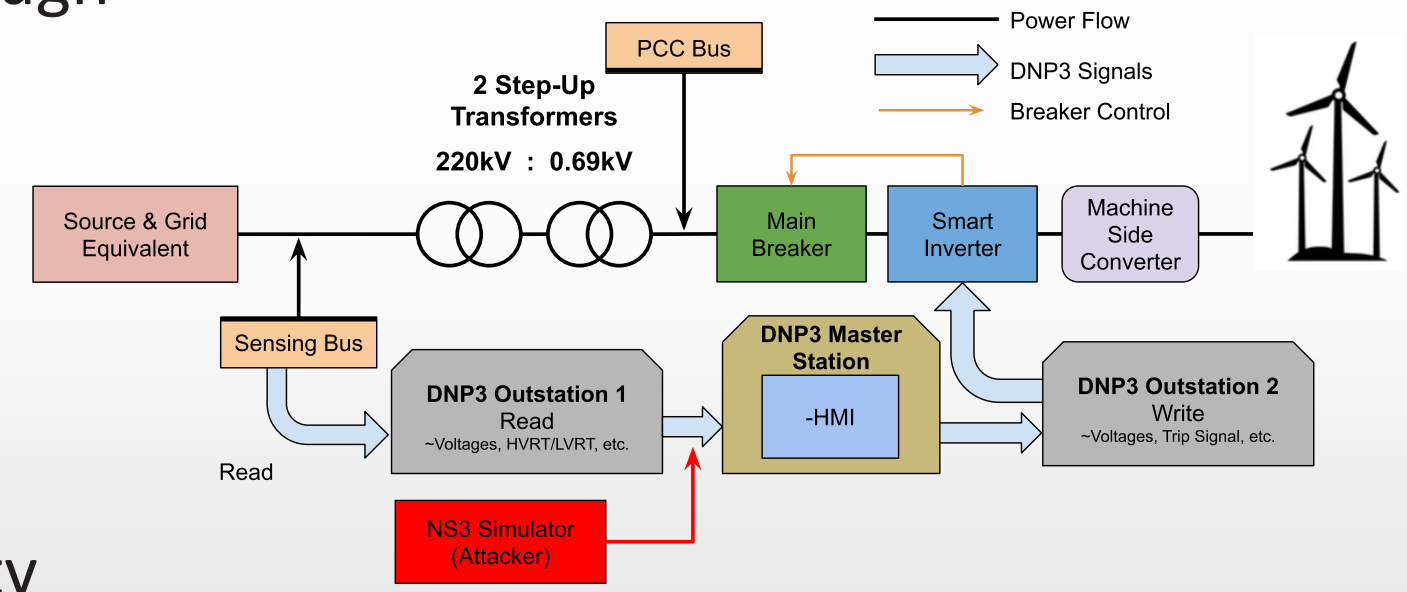
$$T_{VRT} = 0.7\ \text{s} + \frac{4\ \text{s}}{1\ \text{p.u.}}(V - 0.7\ \text{p.u.})$$

- Grid Support Functions lost after Inverter is Blocked



Future Work

- Implement frequency ride through and breaker control
- Redesign DER to support a distribution grid
- Design testbed for cybersecurity studies



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Question and Answers

Major Points:

1. IEEE Std. 1547-2018 outlines interconnection and interoperation of DERs with electrical power system
2. Altered RSCAD's RMS meter to better abide by IEEE Std. and counter numerical errors
3. Implemented logic for ride-through grid support functions using RSCAD's built-in library
4. Demonstrated ride-through and cease energization for zones UV1 and OV1