WEBINAR AND DEMO: Modelling Protection & Control for IEEE 1547™-Compliant DER Interconnection

RTDS Technologies

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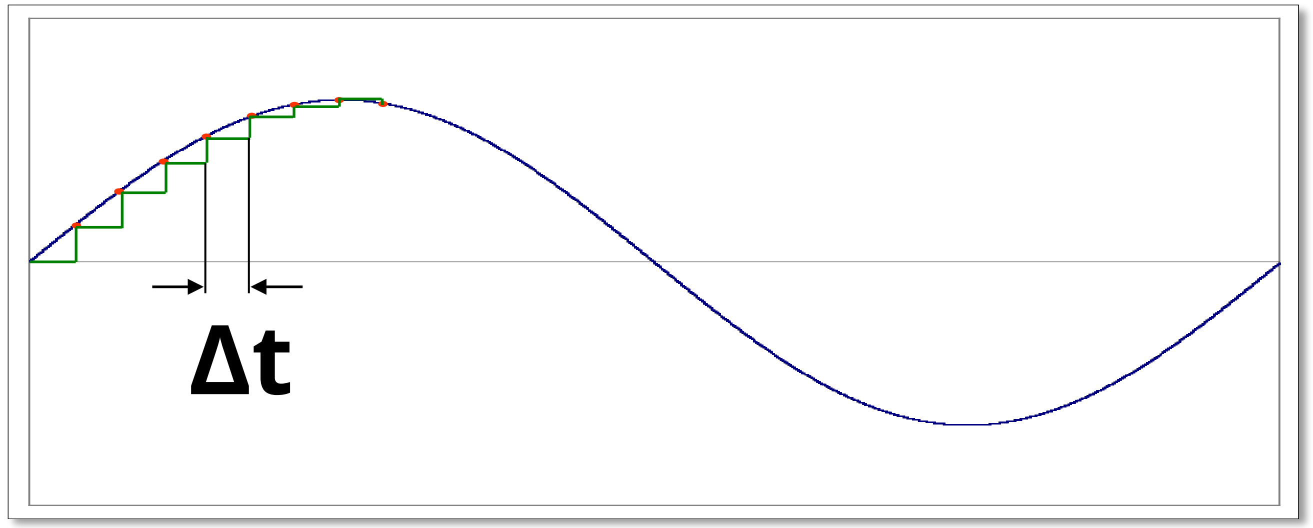
About RTDS Technologies

- Headquarters in Winnipeg, Canada
- Pioneered real-time power system simulation in the 1980s
- The RTDS Simulator is the industry standard for real-time simulation and closed-loop testing, used by utilities, manufacturers, research and educational institutions, and consultants worldwide
- Learn more at www.rtds.com or the large library of videos on the RTDS Technologies YouTube channel

EMT SIMULATION

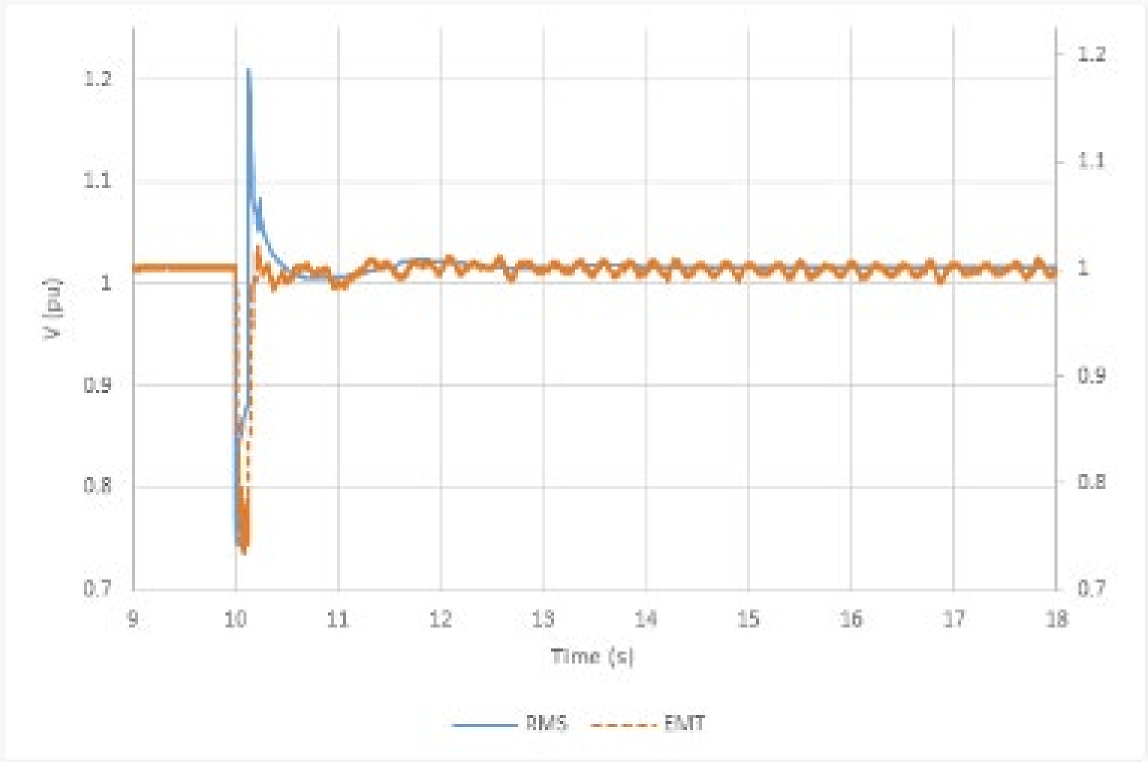
Type of Simulation	Load Flow	Transient Stability Analysis (TSA)	Electromagnetic Transient (EMT)
Typical timestep	Single solution	~ 8 ms	~ 2 - 50 μs
Output	Magnitude and angle	Magnitude and angle	Instantaneous values
Frequency range	Nominal frequency	Nominal and off-nominal frequency	0 – 3 kHz (<15 kHz)



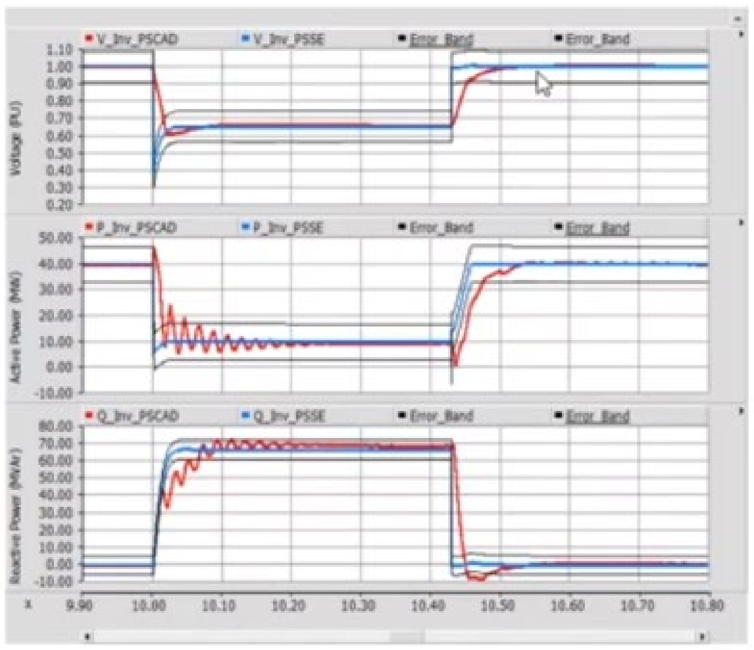
Dommel algorithm of nodal analysis used in RTDS, PSCAD, EMTP, etc.

ADVANTAGES OF EMT SIMULATION

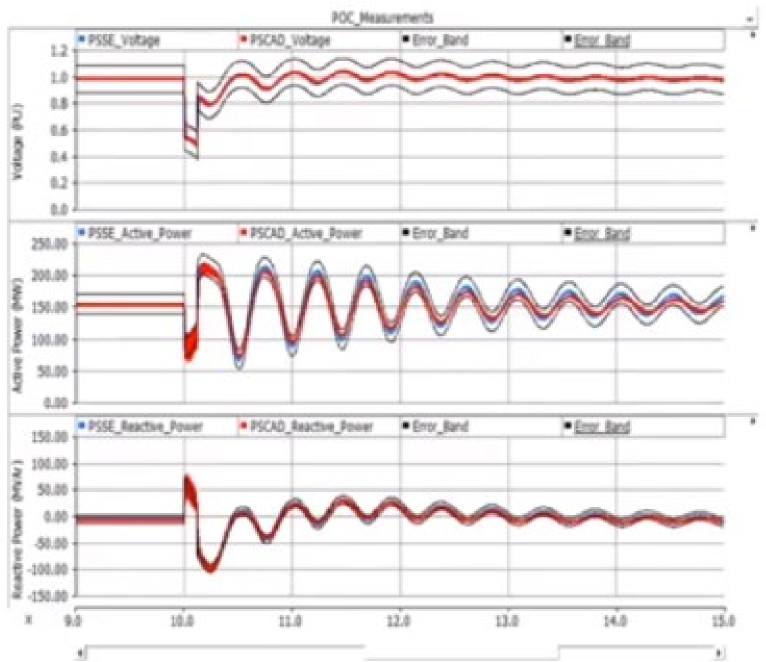
- Allows for a greater depth of analysis than phasor domain (RMS) representations
- RMS models lack the ability to capture fast network dynamics during transient conditions and may provide optimistic results
- Important for modern systems with many power electronic converters (more likely to predict control instability)



Wind farm fault ride through



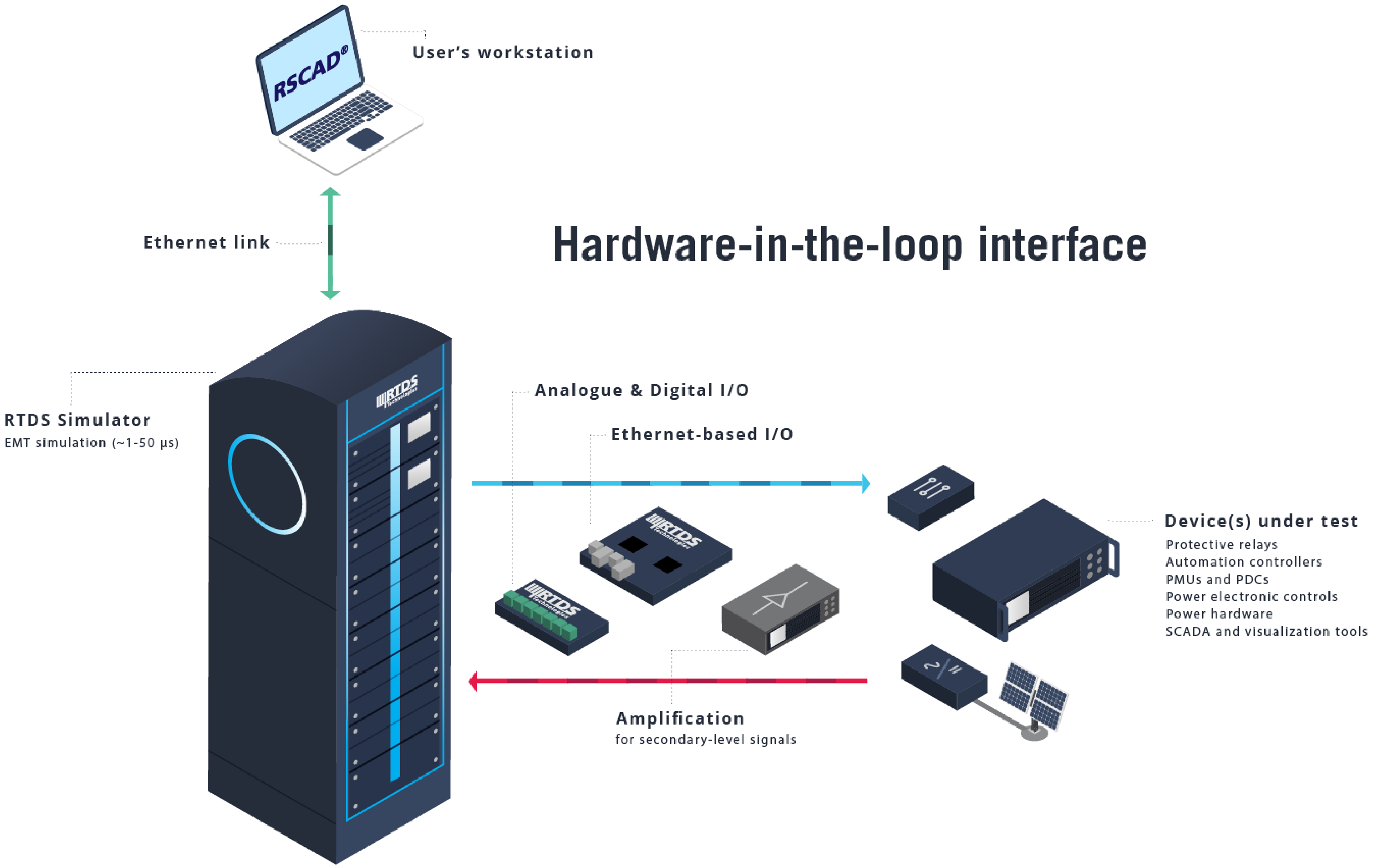
Synchronous generator fault ride through



WHAT IS REAL TIME?

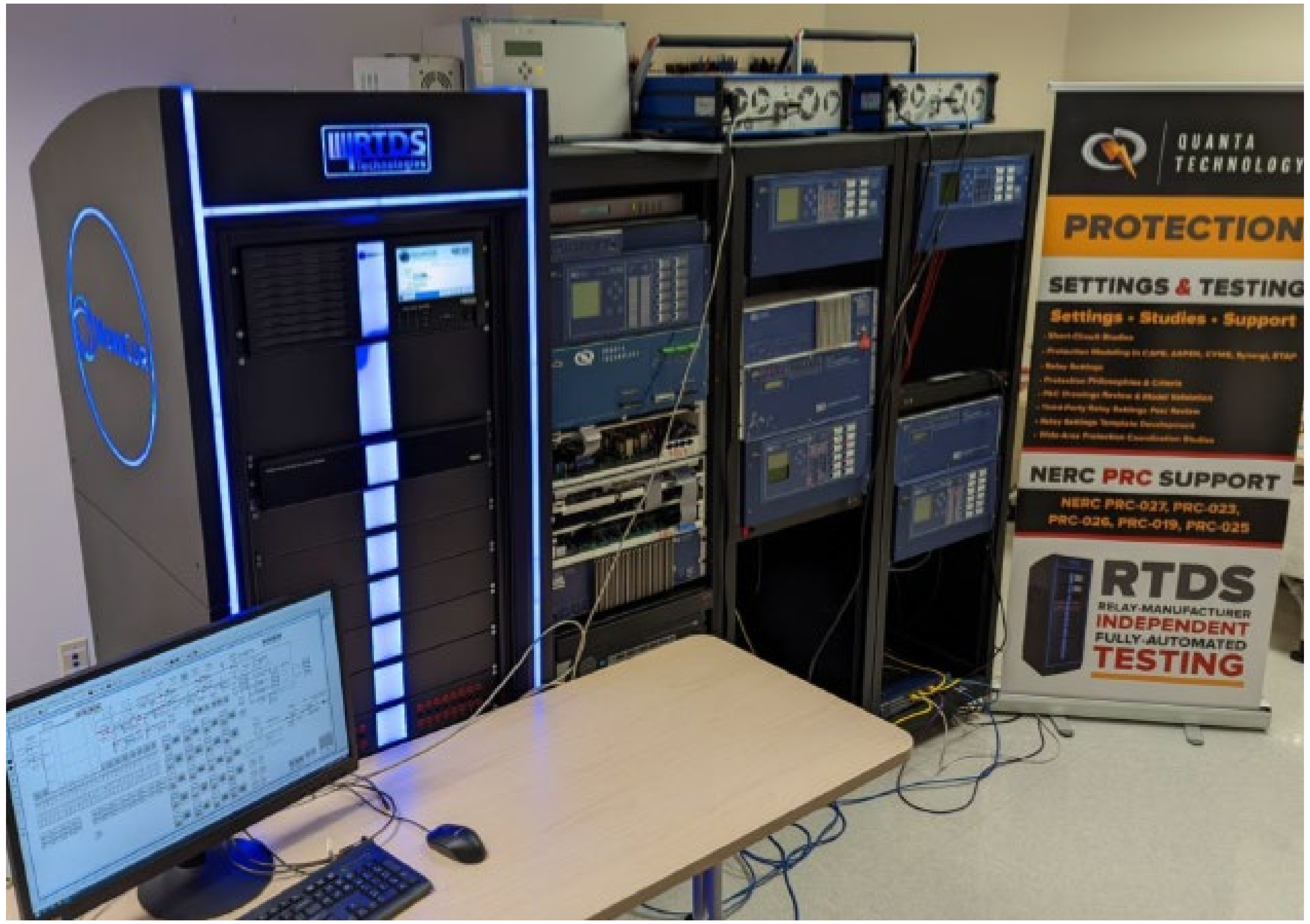
- **Real time operation** is what allows us to connect physical devices in a closed loop with the simulated environment **(hardware-in-the-loop)**

- **True closed-loop testing** is only possible with a real time simulator



DER MODELLING AND TESTING APPLICATIONS

- DER integration studies
    - Black box control model integration
- Impacts/interactions of DERs with existing automation
- Grid-forming control testing
- Inverter testing
- PPC testing
- Replica testing



Quanta Technology's testbed for studying impacts of DER on protection for a utility customer

GTSOC – BLACK BOX CONTROL INTEGRATION

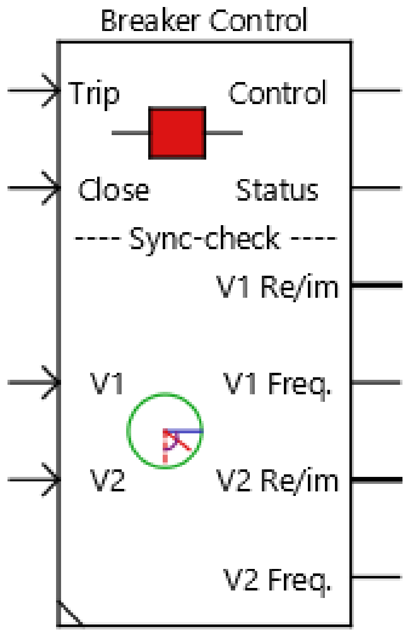
- Features a powerful FPGA board with multi-processor system-on-a-chip technology to facilitate the integration of black box control models into the real-time simulation

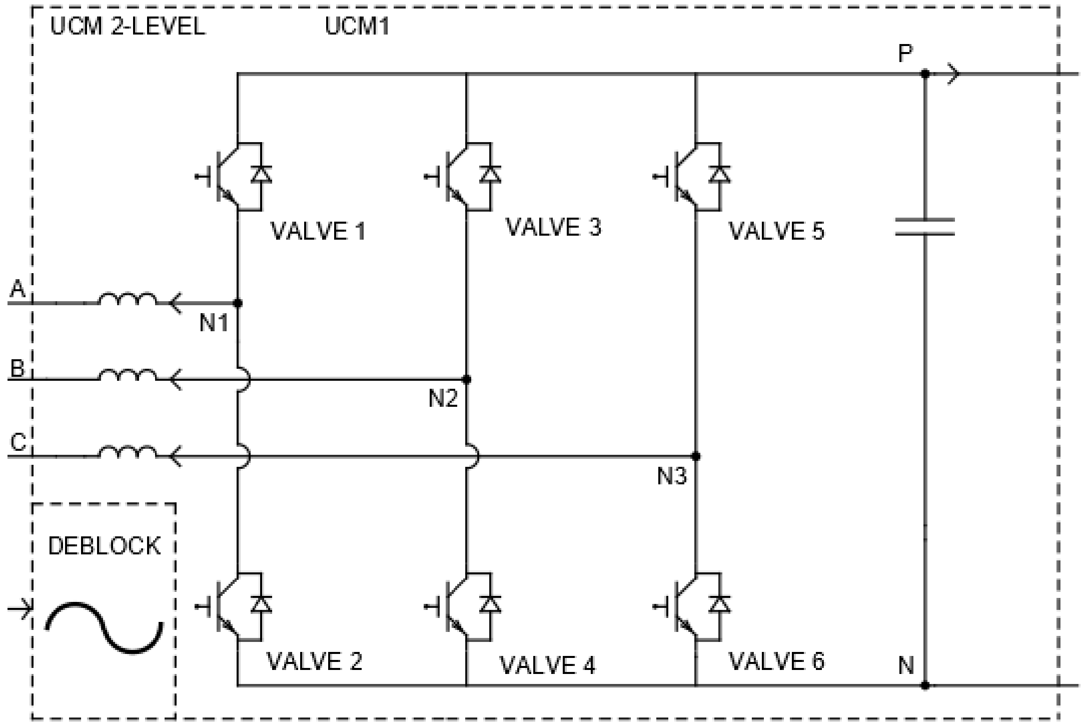
- Vendor can provide DER control model to customer while protecting IP

- Similar to .dll files (PSCAD), but uses .a files to achieve deterministic real-time operation

FEATURES OF TODAY'S CASE

- New Sample Case available in RSCAD FX 1.2 and up
- Compiles on one core of NovaCor
- Protection & control modelled in RSCAD – I/O could be added for external P&C testing
- 2-level Universal Converter Model with Modulation Waveform input – Mainstep environment





UNIVERSAL CONVERTER MODEL

- Model VSCs in both the Substep (1-10 us) and Mainstep (typically 25-50 us) environments
- Simulation environment (i.e. timestep) and model input determine **performance** and **processing load** of converter model
- Modulation Wave Input: no detailed switching (average value model)
- Improved Firing Input:
  - Substep (1-10 us): Accurately represents switching frequencies up to **~150 kHz**
  - Mainstep (25-50 us): Accurately represents switching frequencies up to **10 kHz**

Note: Both Mainstep options require 10 load units per converter.
Using Improved Firing does not increase the processing load.

Thank you!
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WEBINAR

MODELLING PROTECTION AND CONTROL FOR IEEE 1547™–COMPLIANT DER INTERCONNECTION

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OUTLINE

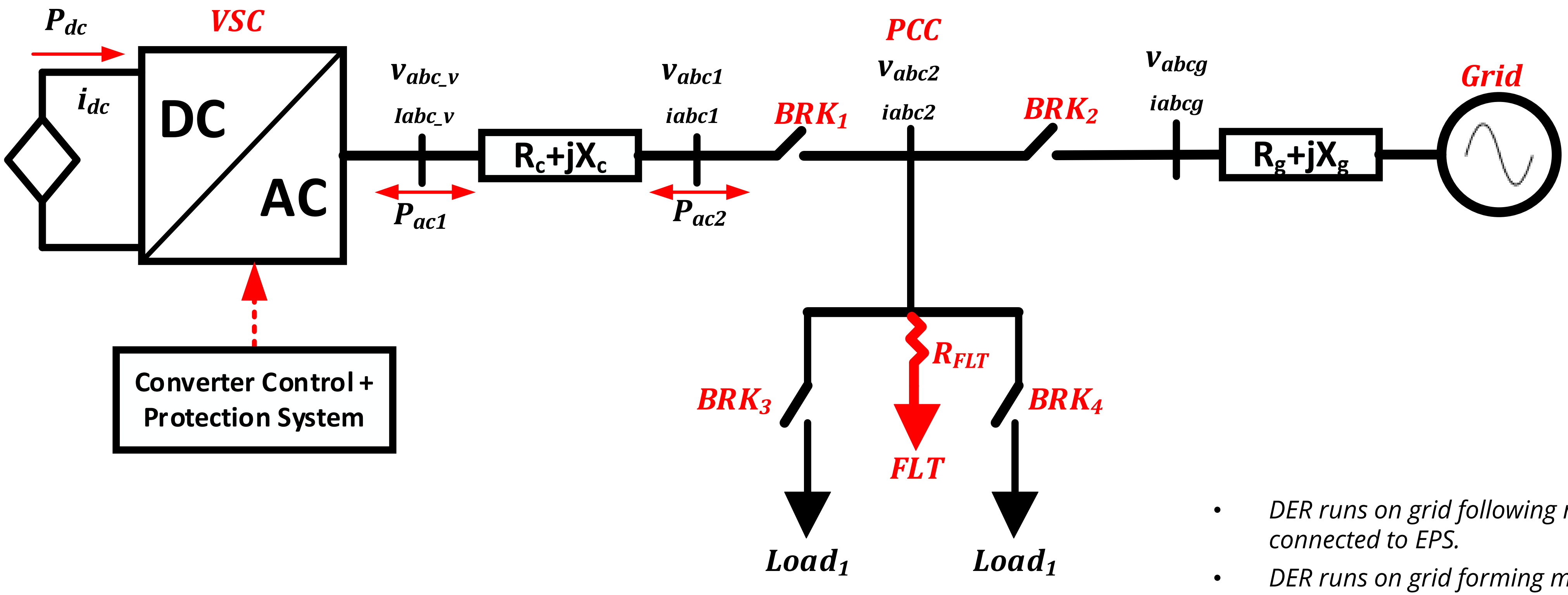
- Introduction.
- Protection and Control Modelling.
- Demonstration.
- Questions and Answers.

INTRODUCTION

- **IEEE Std 1547™-2018 –**
  - IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources (DER) with Associated Electric Power Systems Interfaces.
  - Addresses consensus standard **technical requirements for DER interconnection** by providing uniform criteria and requirements relevant to the performance, operation, and testing of the interconnection.

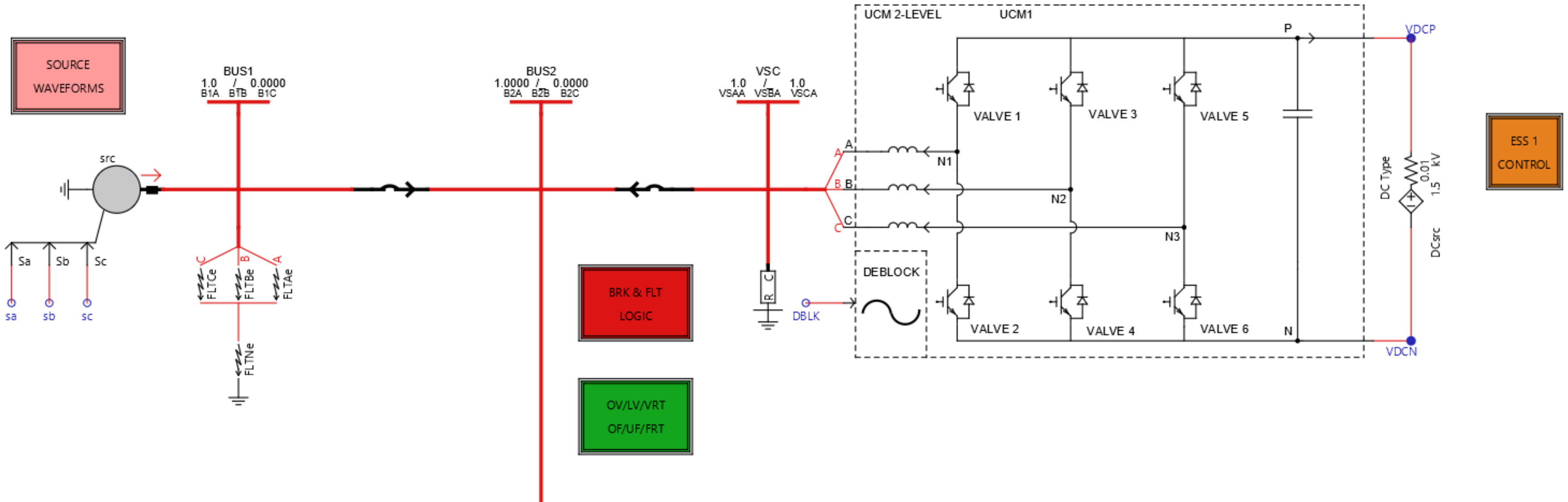
- Key criteria –
  - Synchronization of the DER to an Area Electric Power System (EPS).
  - Response to the Area EPS abnormal conditions –
    - ➢ Undervoltage (UV), Overvoltage (OV), and Voltage Disturbance Ride-Through.
    - ➢ Underfrequency (UF), Overfrequency (OF), and Frequency Disturbance Ride-Through.

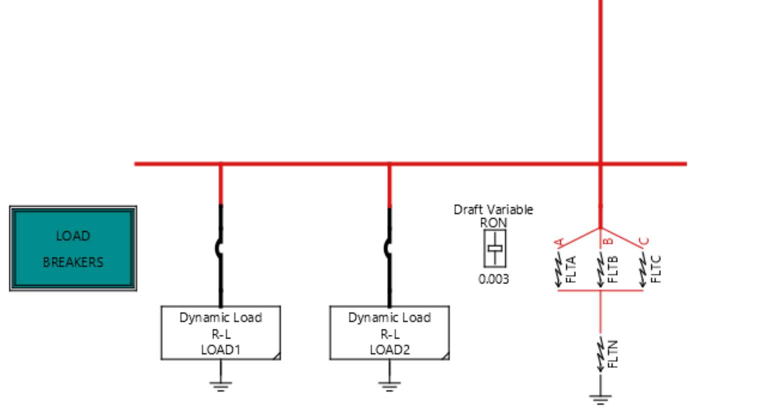
POWER SYSTEM NETWORK

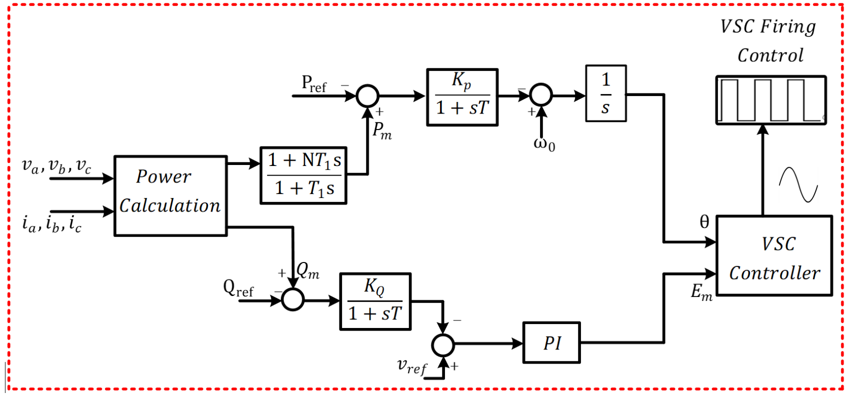


- *DER runs on grid following mode when connected to EPS.*
- *DER runs on grid forming mode with droop control when islanded.*

SIMULATION MODELING





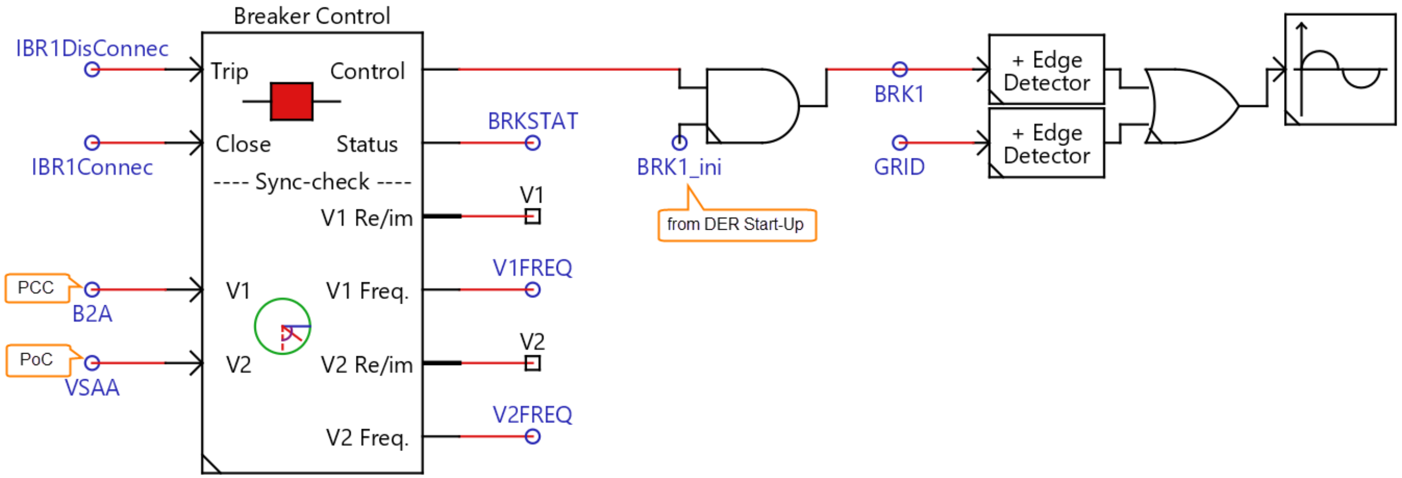


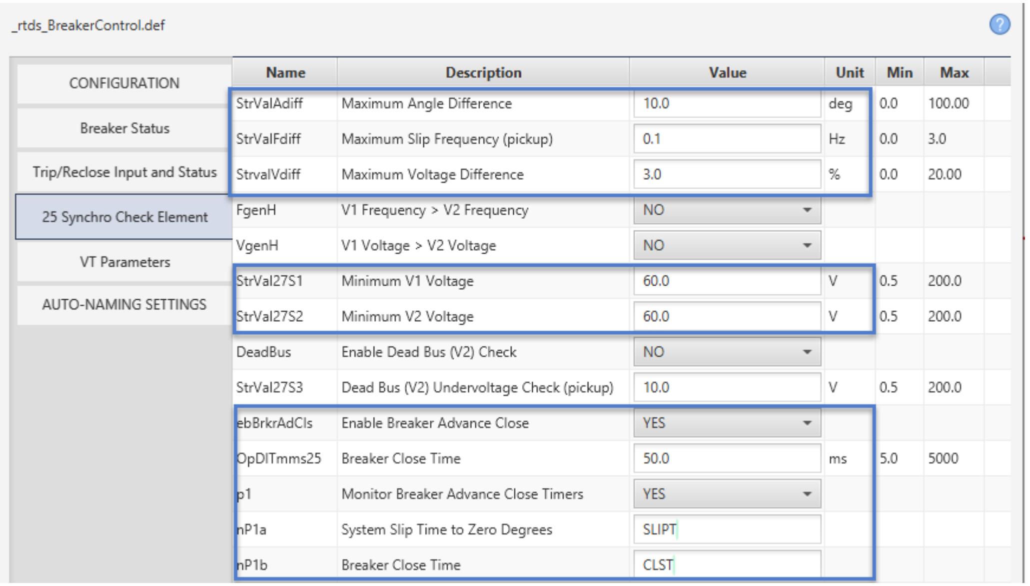
Droop Control of GFC

SYNCHRONIZATION OF DER TO GRID

Rating of DER Units (kVA)	Frequency Difference (Δf, Hz)	Voltage Difference (ΔV, %)	Phase Angle Difference (Δϕ, °)
> 1500	0.1	3	10

Ref: IEEE 1547-2018

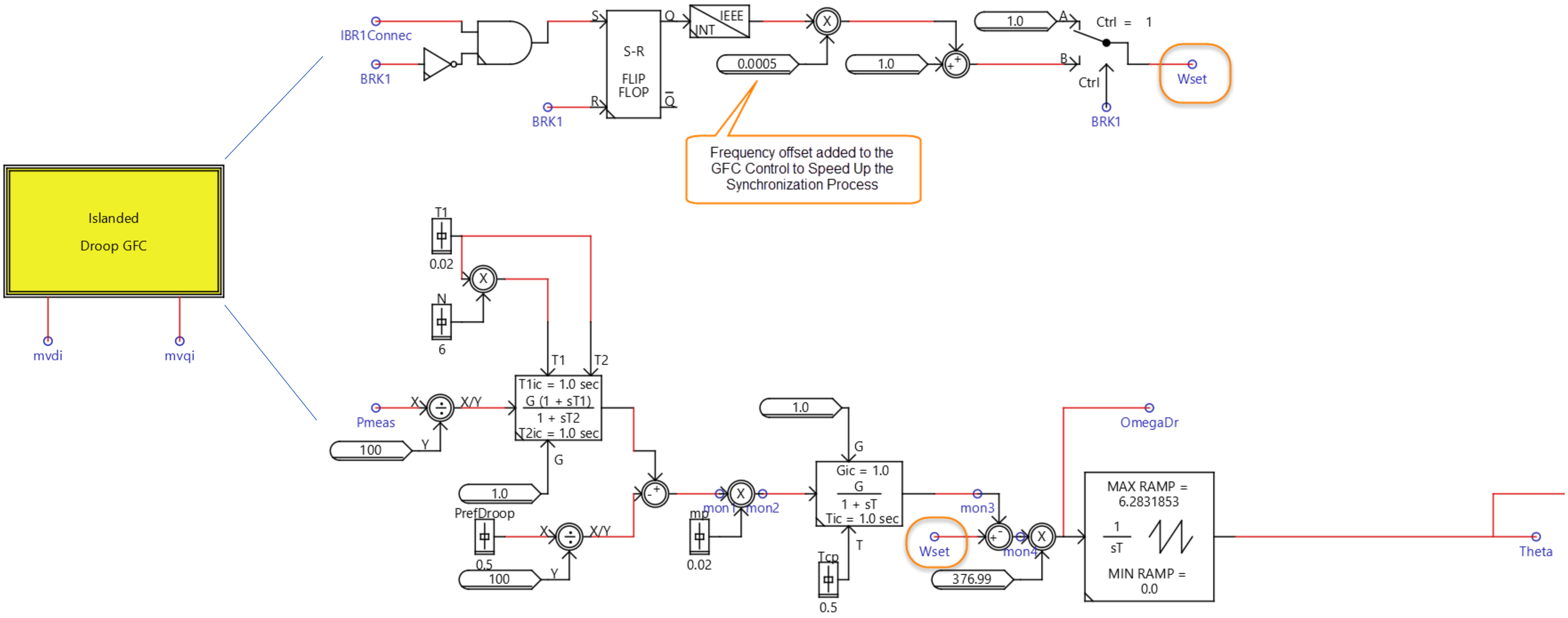



_rtds_BreakerControl.def

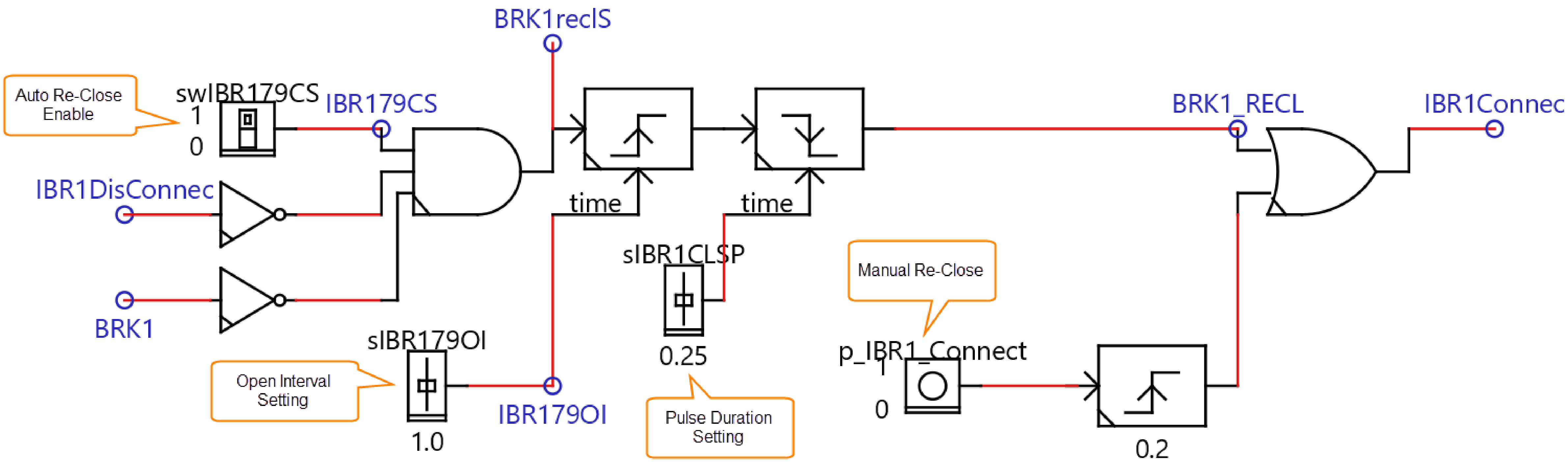
CONFIGURATION
Breaker Status
Trip/Reclose Input and Status
25 Synchro Check Element
VT Parameters
AUTO-NAMING SETTINGS

Name	Description	Value	Unit	Min	Max
StrValAdiff	Maximum Angle Difference	10.0	deg	0.0	100.00
StrValFdiff	Maximum Slip Frequency (pickup)	0.1	Hz	0.0	3.0
StrvalVdiff	Maximum Voltage Difference	3.0	%	0.0	20.00
FgenH	V1 Frequency > V2 Frequency	NO			
VgenH	V1 Voltage > V2 Voltage	NO			
StrVal27S1	Minimum V1 Voltage	60.0	V	0.5	200.0
StrVal27S2	Minimum V2 Voltage	60.0	V	0.5	200.0
DeadBus	Enable Dead Bus (V2) Check	NO			
StrVal27S3	Dead Bus (V2) Undervoltage Check (pickup)	10.0	V	0.5	200.0
ebBrkrAdCls	Enable Breaker Advance Close	YES			
OpDlTmms25	Breaker Close Time	50.0	ms	5.0	5000
p1	Monitor Breaker Advance Close Timers	YES			
nP1a	System Slip Time to Zero Degrees	SLIPT			
nP1b	Breaker Close Time	CLST			

SYNCHRONIZATION OF DER TO GRID



RECLOSING LOGIC



VOLTAGE DISTURBANCES – TRIP/LVRT/OVRT

Table 14—Voltage ride-through requirements for DER for abnormal operating performance Category I (see Figure H.7)

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

Category I

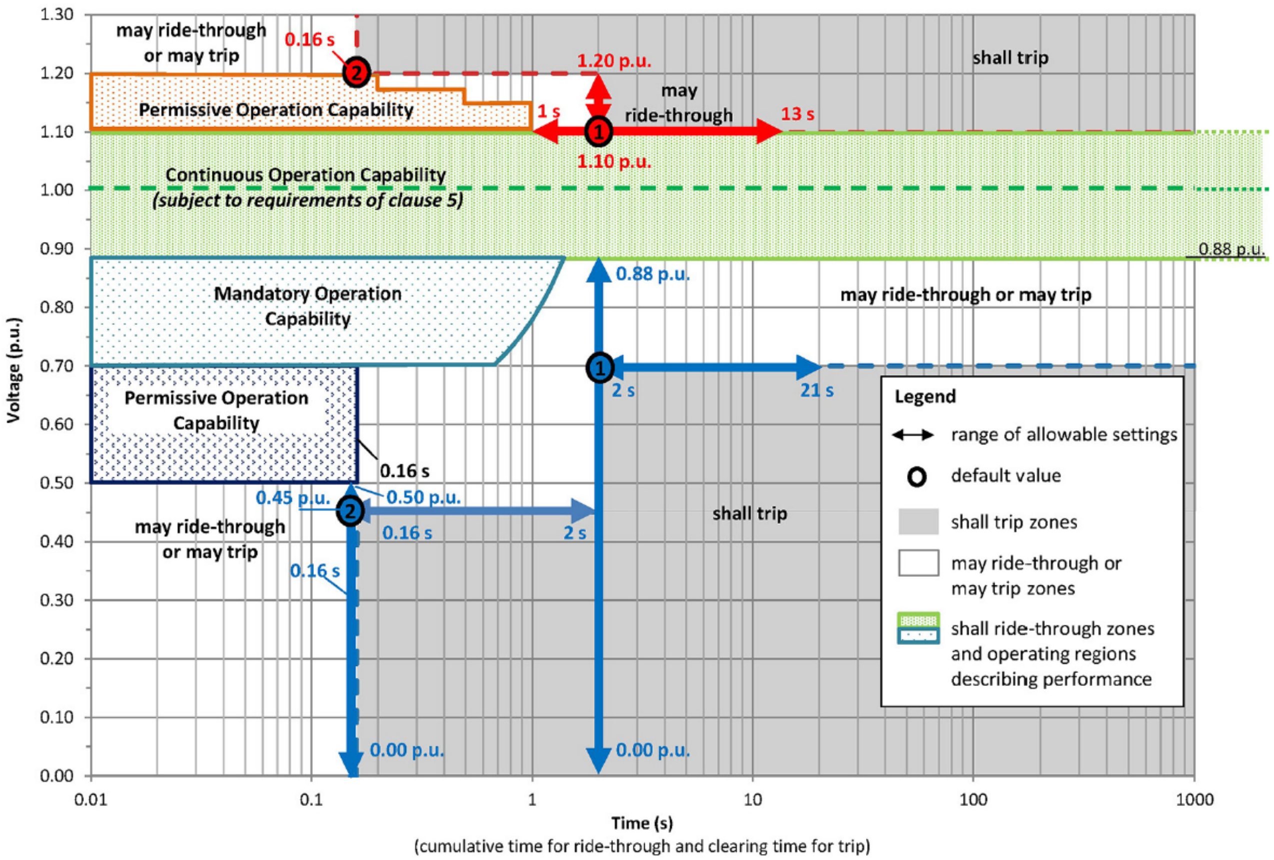
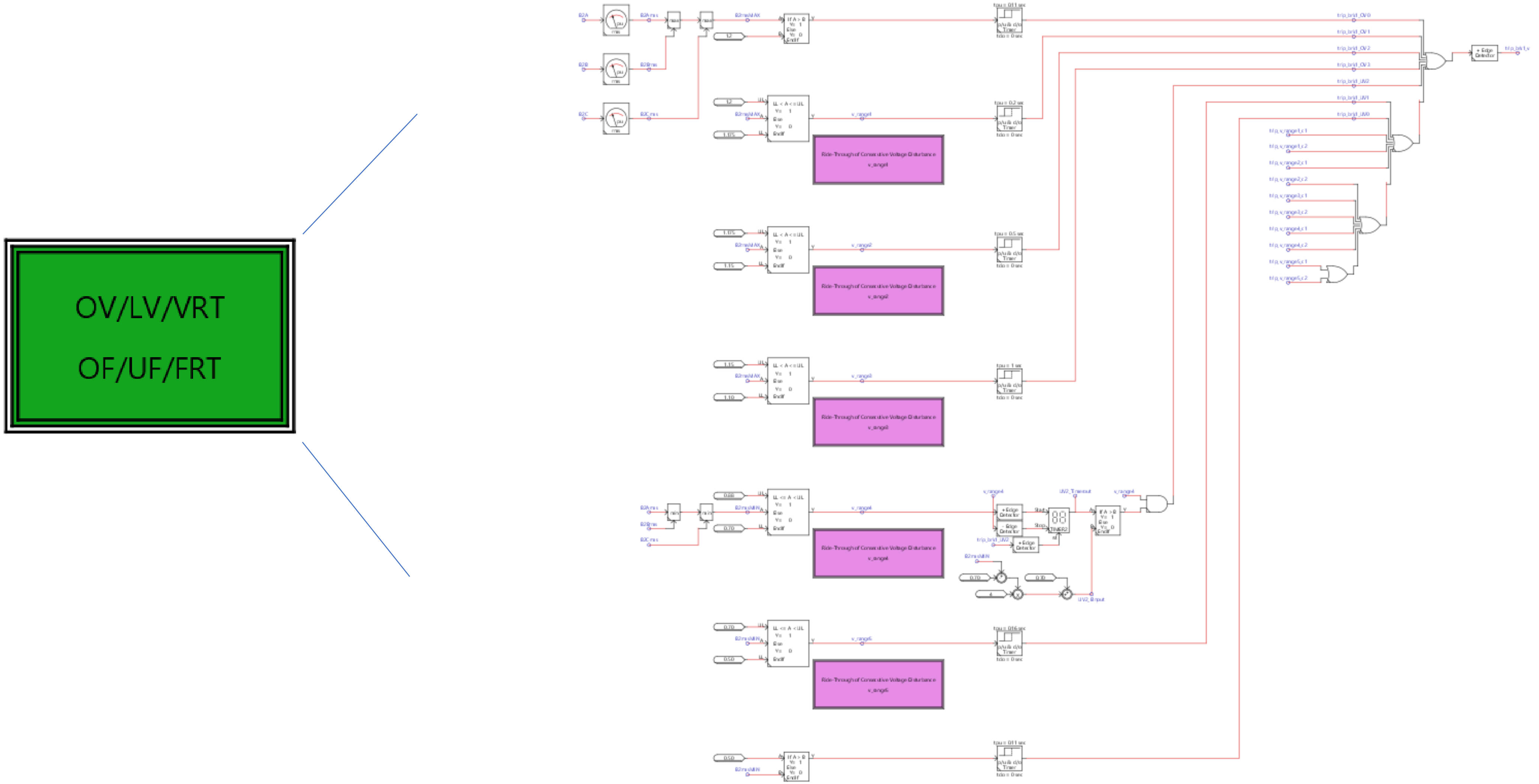


Figure H.7—DER response to abnormal voltages and voltage ride-through requirement for DER of abnormal operating performance Category I

Ref: IEEE 1547-2018

VOLTAGE DISTURBANCES – MODELING



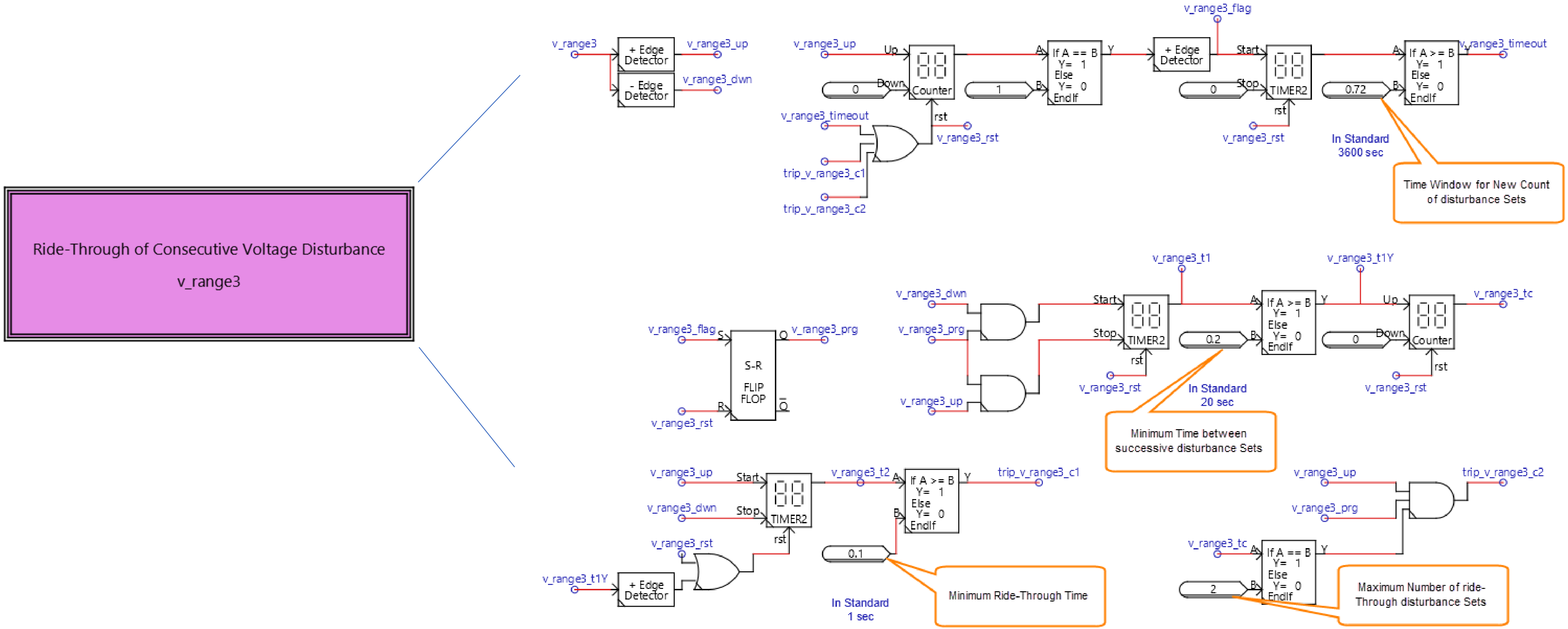
RIDE-THROUGH OF CONSECUTIVE VOLTAGE DISTURBANCE

Table 17 —Voltage ride-through requirements for consecutive temporary voltage disturbances caused by unsuccessful reclosing for DER of abnormal operating performance Category I, Category II, and Category III

Col. 1	Col. 2	Col. 3	Col. 4
Category	Maximum number of ride-through disturbance sets	Minimum time between successive disturbance sets (s)	Time window for new count of disturbance sets (min)
I	2	20.0	60
II	2	10.0	60
III	3	5.0	20

Ref: IEEE 1547-2018

RIDE-THROUGH OF CONSECUTIVE VOLTAGE DISTURBANCE - MODELING



FREQUENCY DISTURBANCES – TRIP/LFRT/OFRT

Table 19 —Frequency ride-through requirements for DER of abnormal operating performance Category I, Category II, and Category III (see Figure H.10)

Frequency range (Hz)	Operating mode	Minimum time (s) (design criteria)
$f > 62.0$	No ride-through requirements apply to this range	
$61.2 < f \leq 61.8$	Mandatory Operation[a]	299
$58.8 \leq f \leq 61.2$	Continuous Operation[a,b]	Infinite[c]
$57.0 \leq f < 58.8$	Mandatory Operation[b]	299
$f < 57.0$	No ride-through requirements apply to this range	

Table 21 —Rate of change of frequency (ROCOF) ride-through requirements for DER of abnormal operating performance Category I, Category II, and Category III

Category I	Category II	Category III
0.5 Hz/s	2.0 Hz/s	3.0 Hz/s

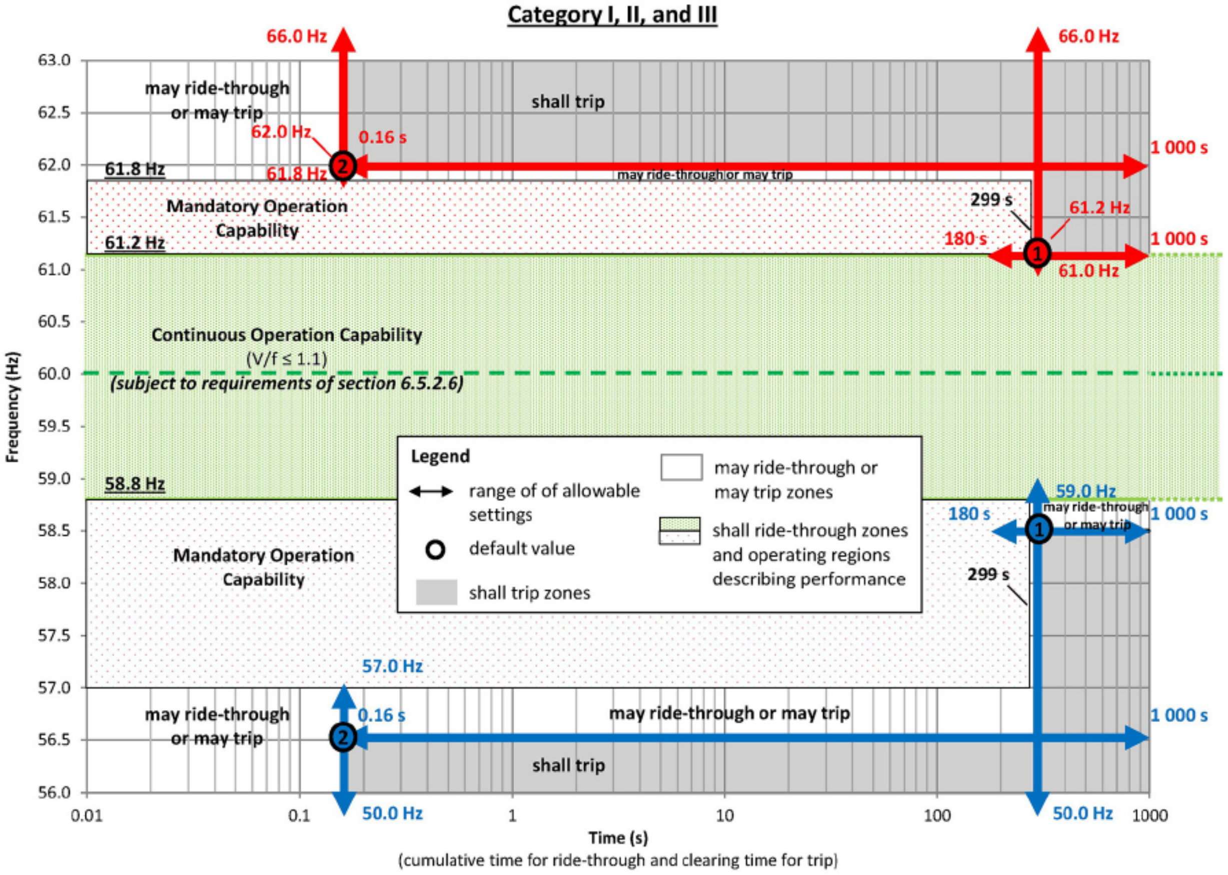
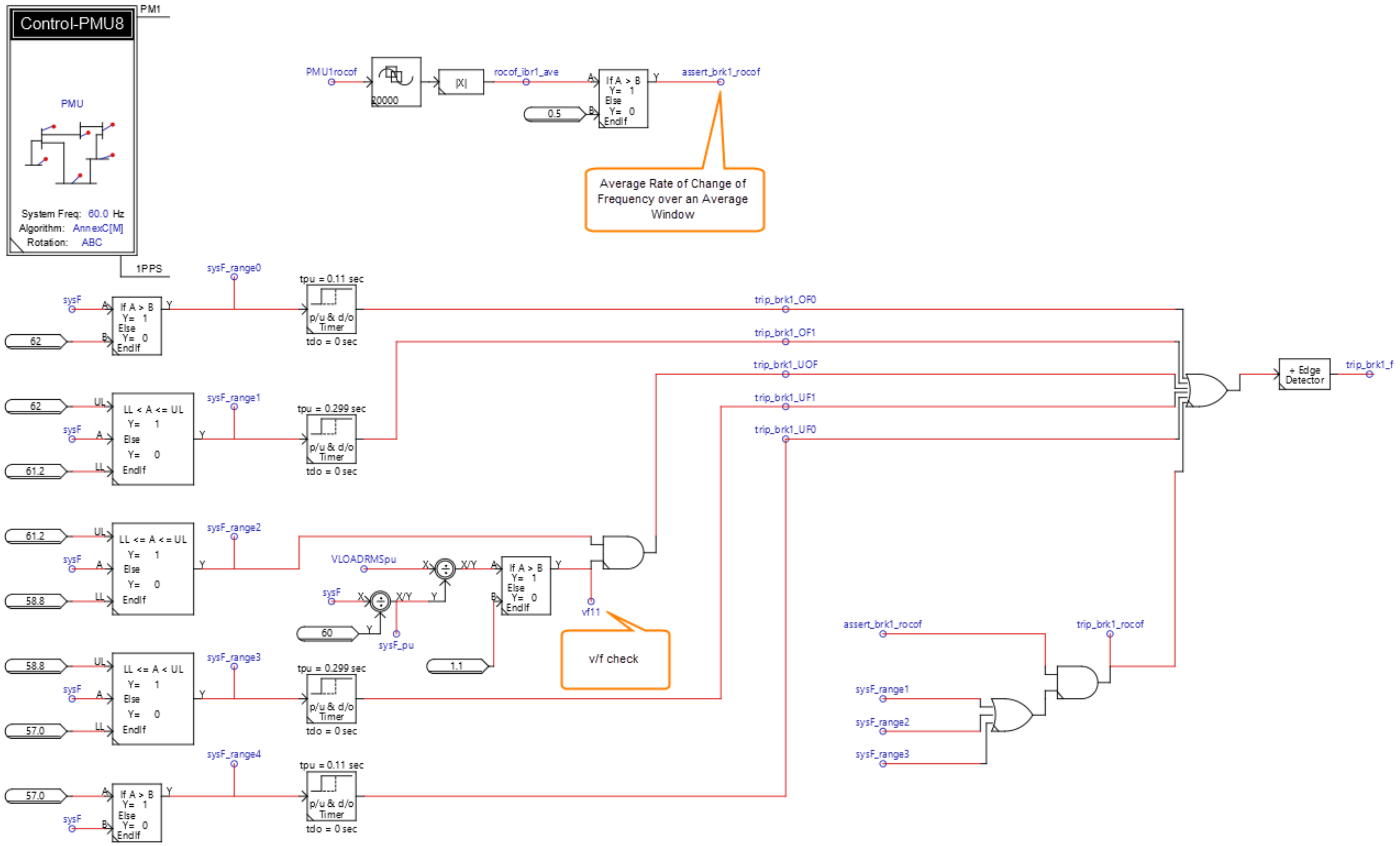


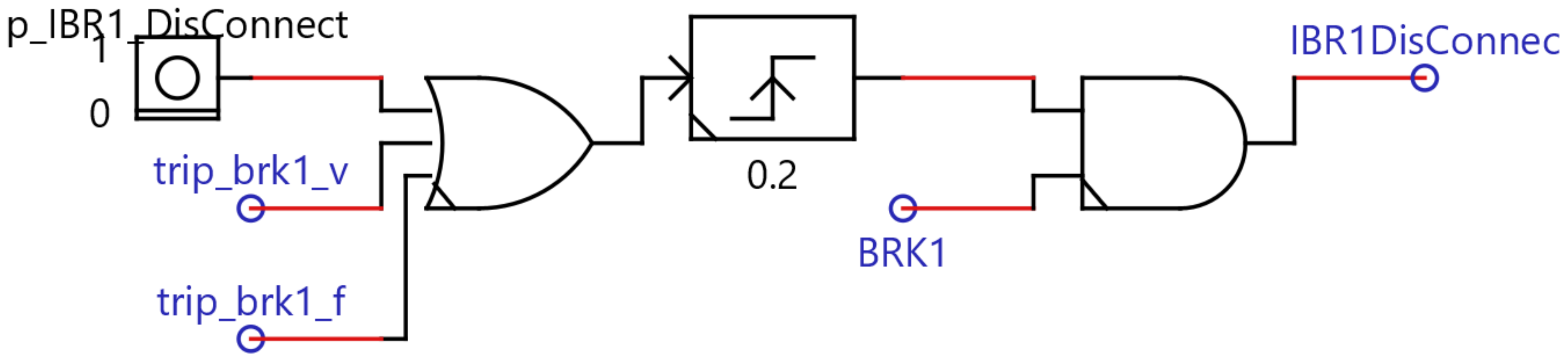
Figure H.10—DER default response to abnormal frequencies and frequency ride-through requirements for DER of abnormal operating performance Category I, Category II, and Category III

Ref: IEEE 1547-2018

FREQUENCY DISTURBANCES – MODELING

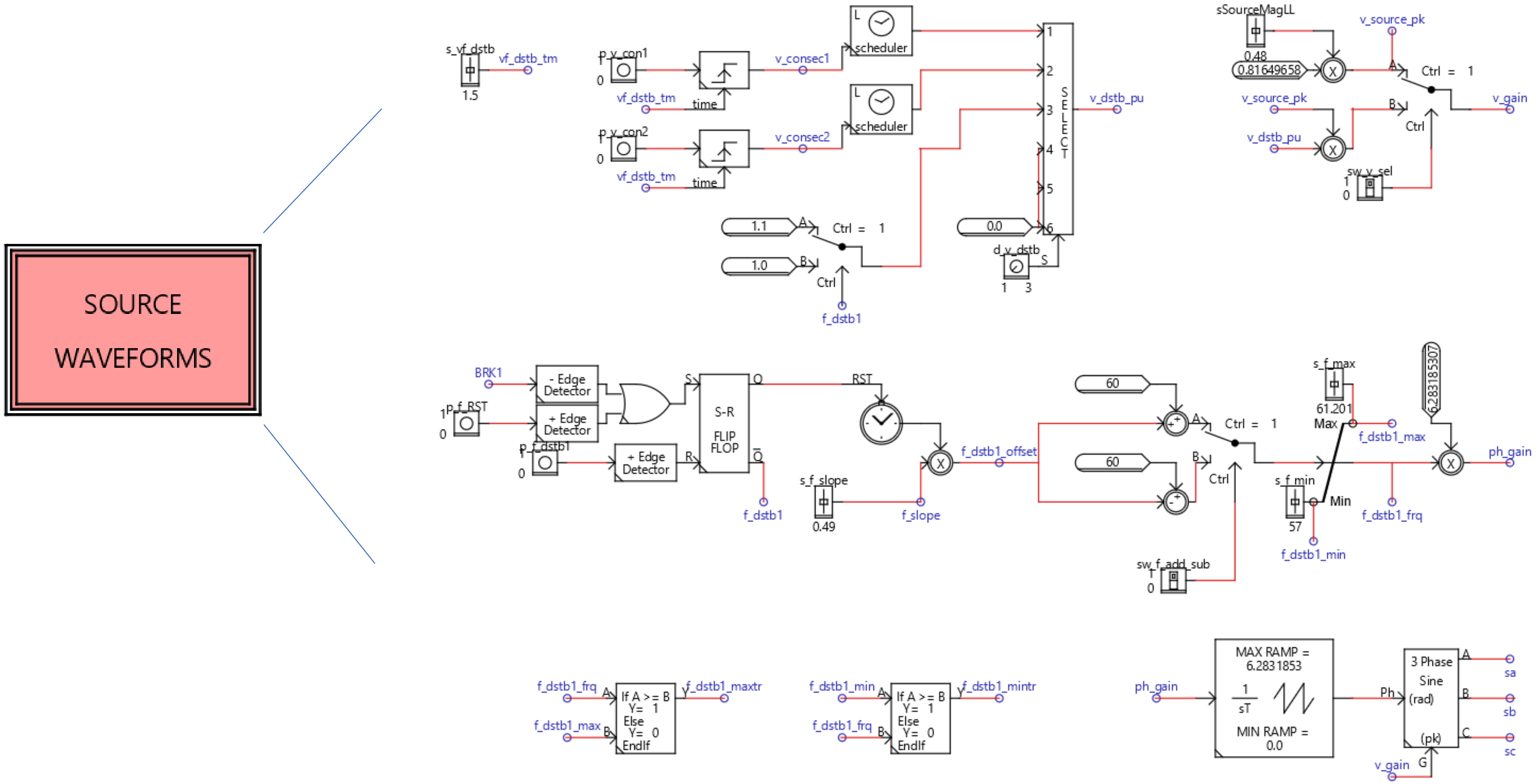


TRIP LOGIC



p_IBR1_DisConnect
1
0
trip_brk1_v
trip_brk1_f
0.2
BRK1
IBR1DisConnec

CONTROLLABLE SOURCE WAVEFORM



RUNTIME DEMO

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THANK YOU!
QUESTIONS?

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