SCHWEITZER ENGINEERING LABORATORIES

TESTING PROTECTION DEVICES WITH INVERTER-BASED RESOURCES

JORDAN BELL

SCHWEITZER ENGINEERING LABORATORIES

2023 North American RTDS TECHNOLOGIES INC. APPLICATIONS & TECHNOLOGY CONFERENCE

2023 NORTH AMERICAN RTDS APPLICATIONS & TECHNOLOGY CONFERENCE

RTDS Technologies AMETEK

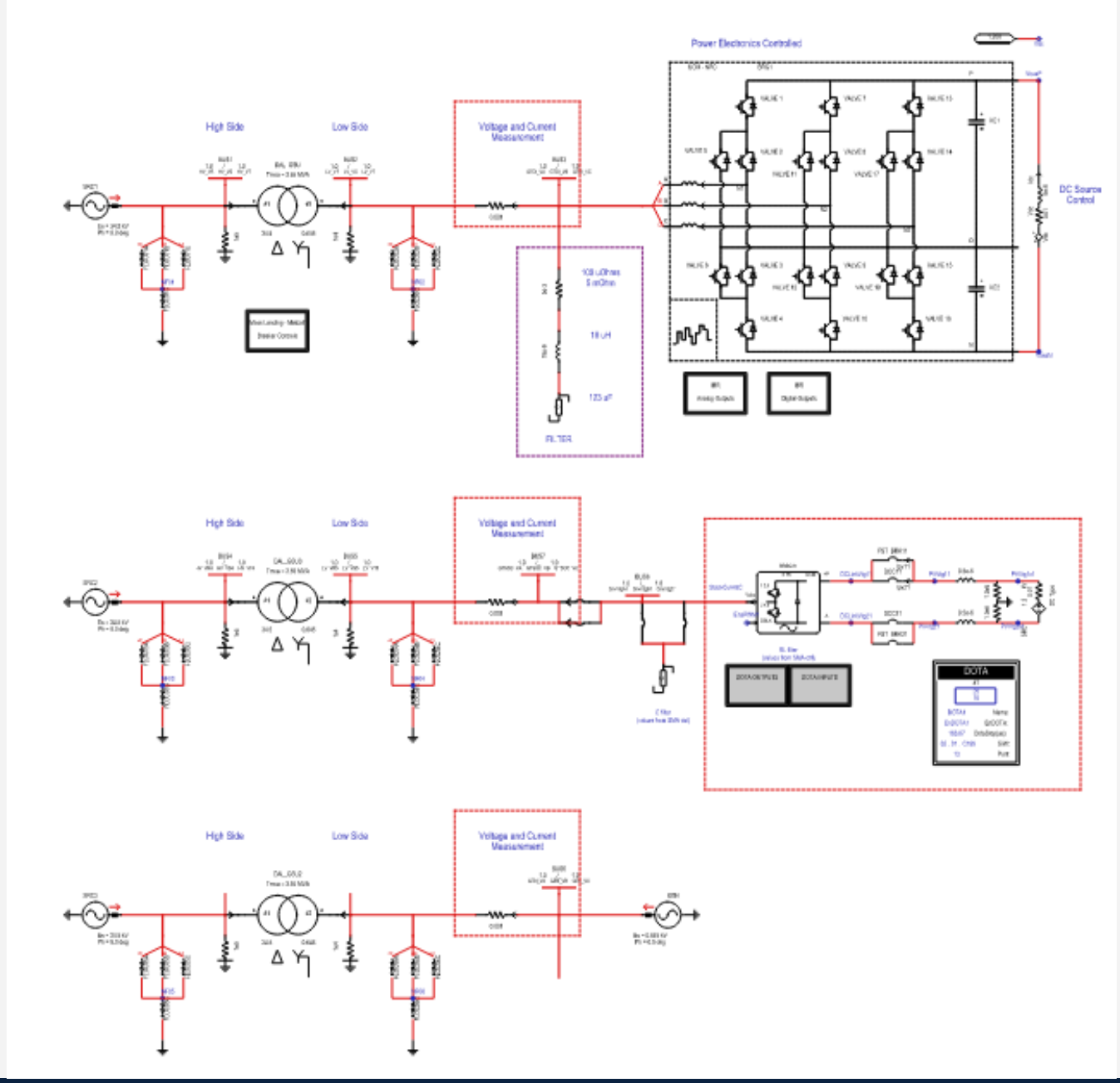
INTRODUCTION

Methods for Testing Protection Devices

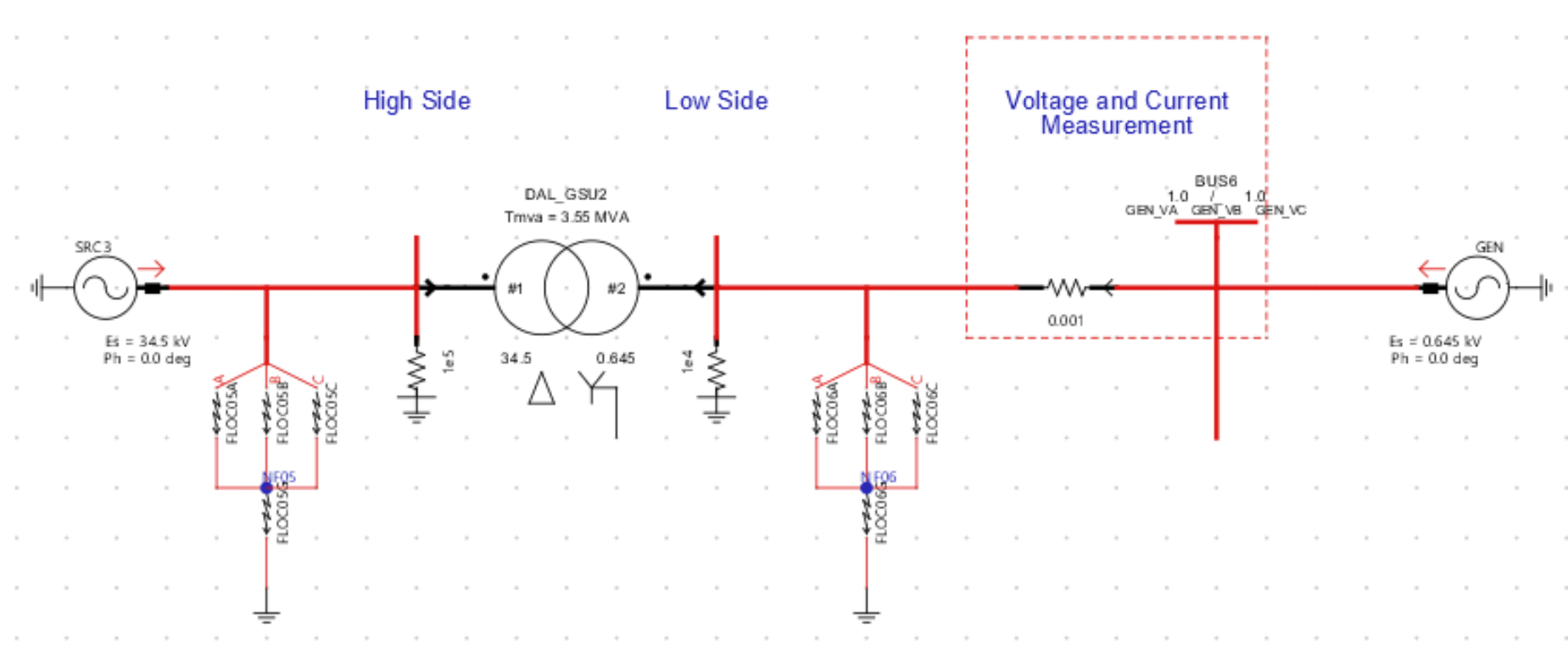
- Inverter-based resources do not operate like typical generators
- Average or custom-built models (reverse engineered) are good for load flow or control testing, but inadequate for testing protection devices
- Two methods, provided by RTDS, tested
  - UCM model controlled by GTSOC interface
  - UCM model controlled by external control board through GTDI UCM interface
- Tests results compared behavior to equivalent source

SYSTEM MODEL

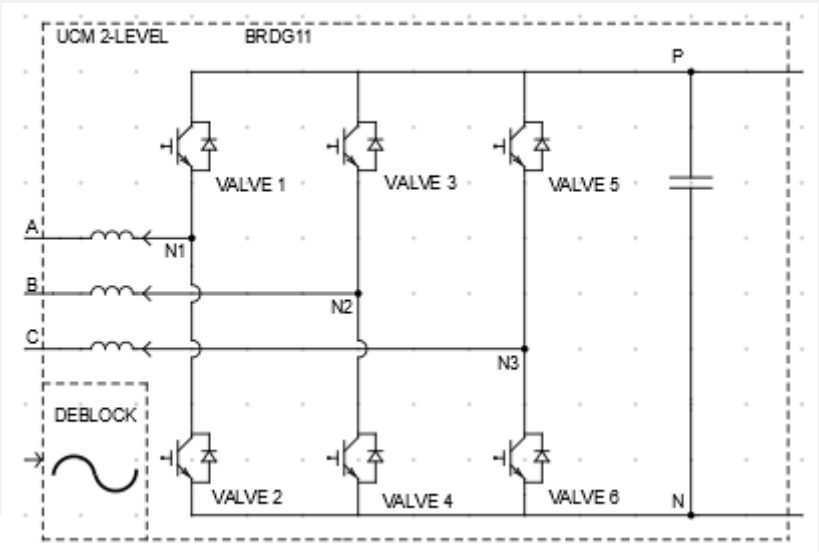
- Generator equivalent
- GTSOC UCM
- GTDI UCM

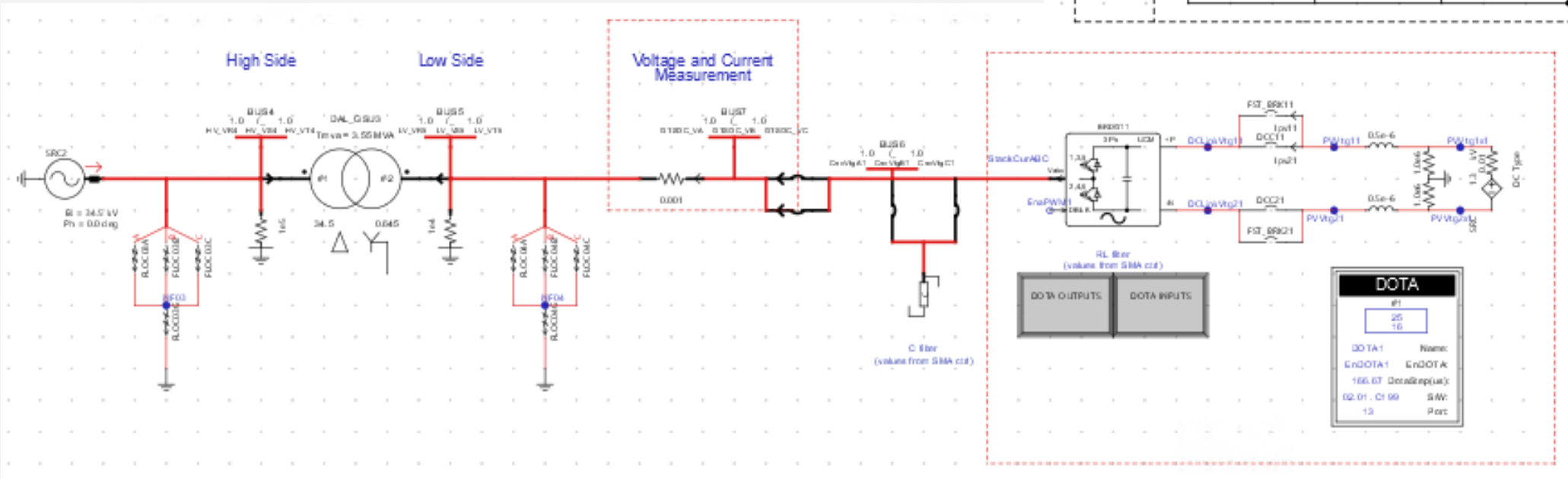


GENERATOR EQUIVALENT

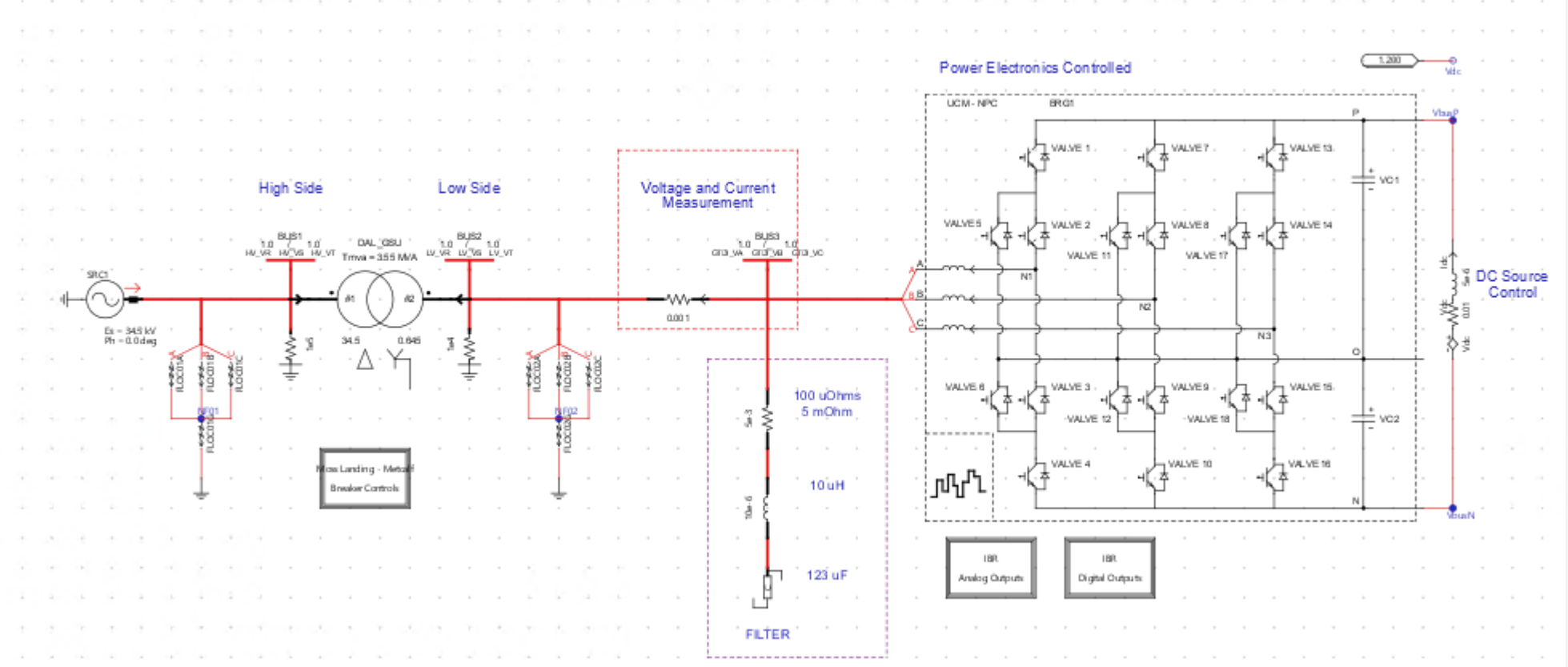


GTSOC UCM MODEL





GTDI UCM MODEL

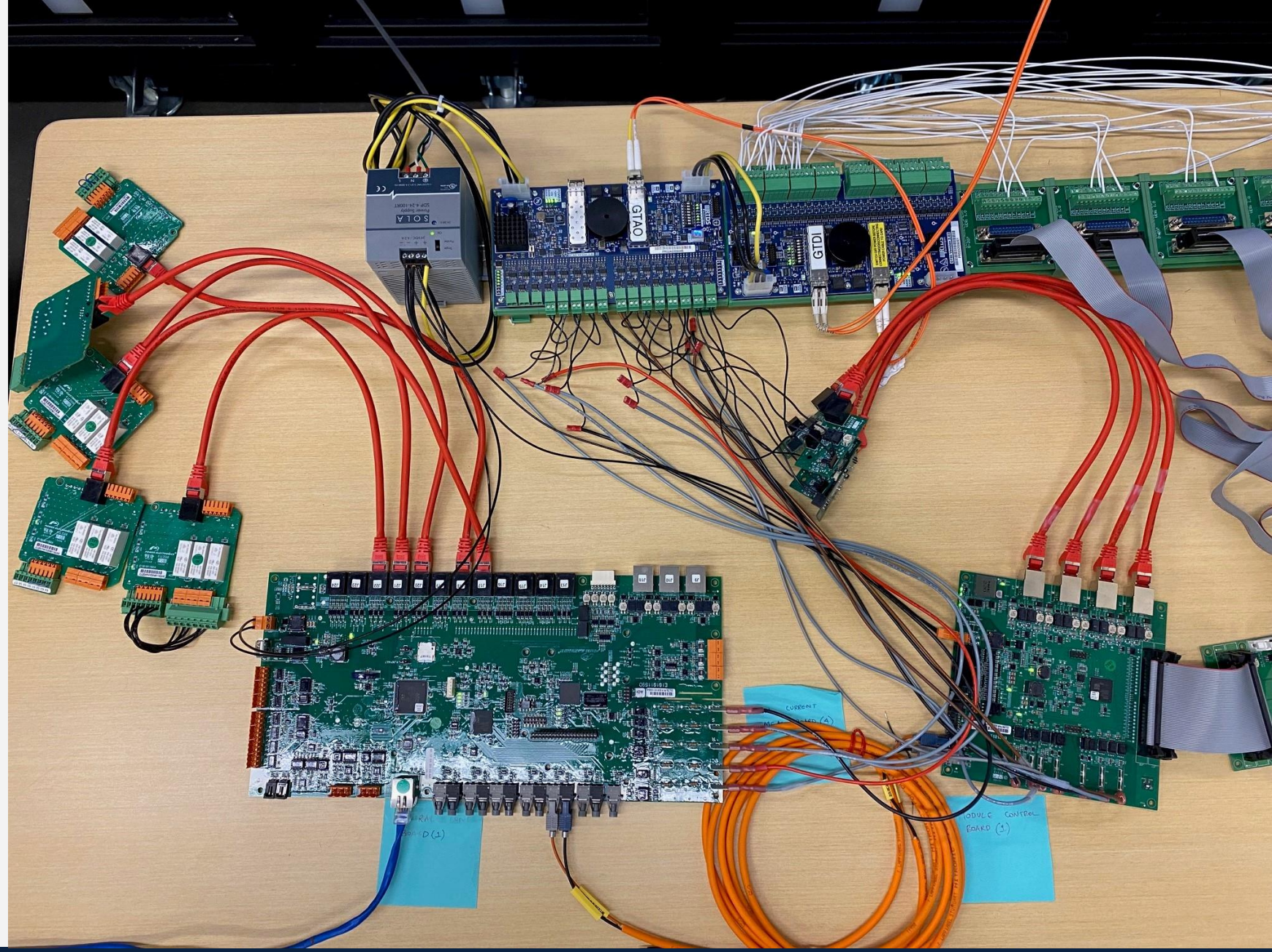


INVERTER BOARD INTERFACE

CONTROL INTERFACE

Central Control Board

Digital I/O Boards

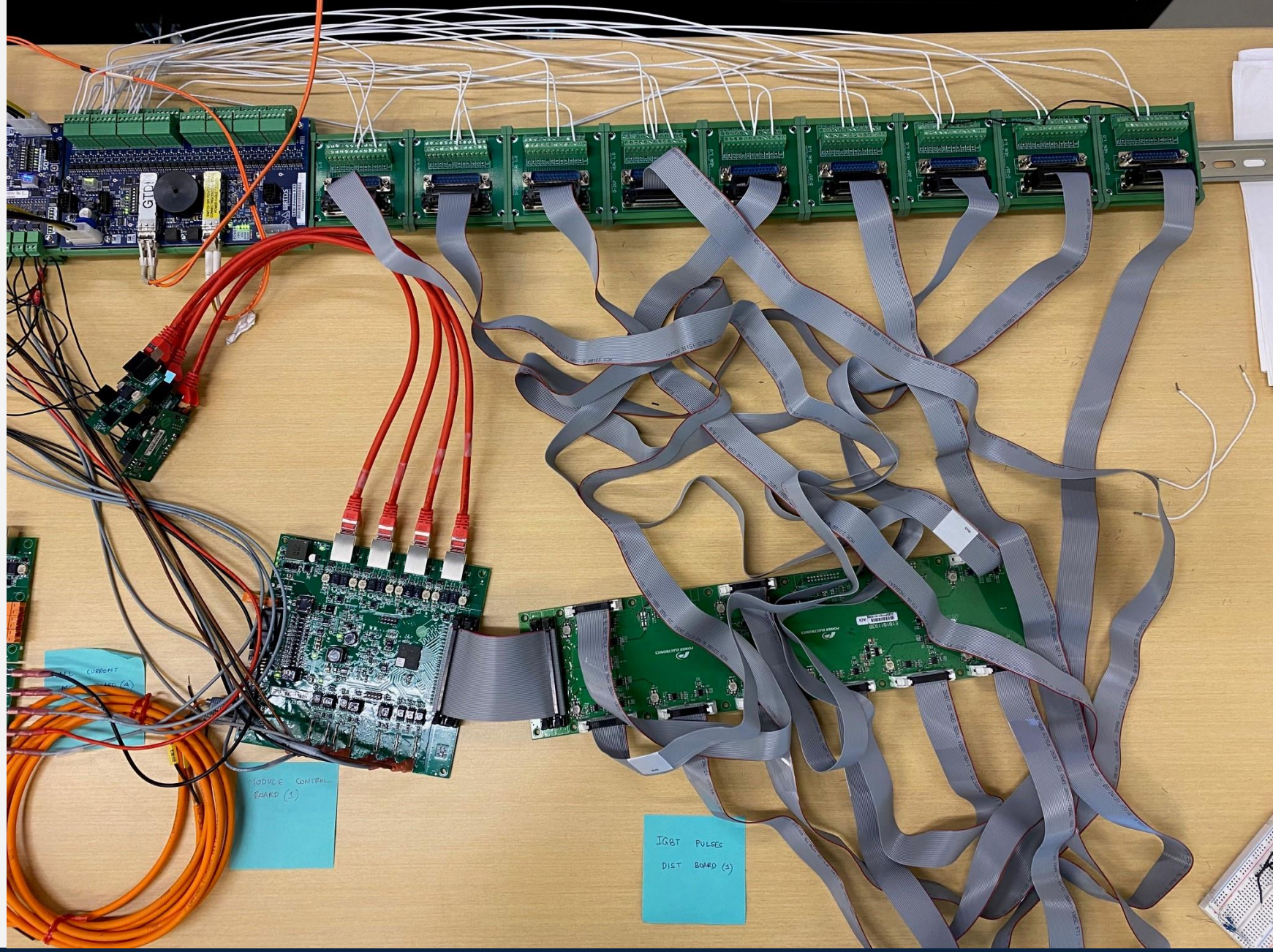


Current Measurement Board

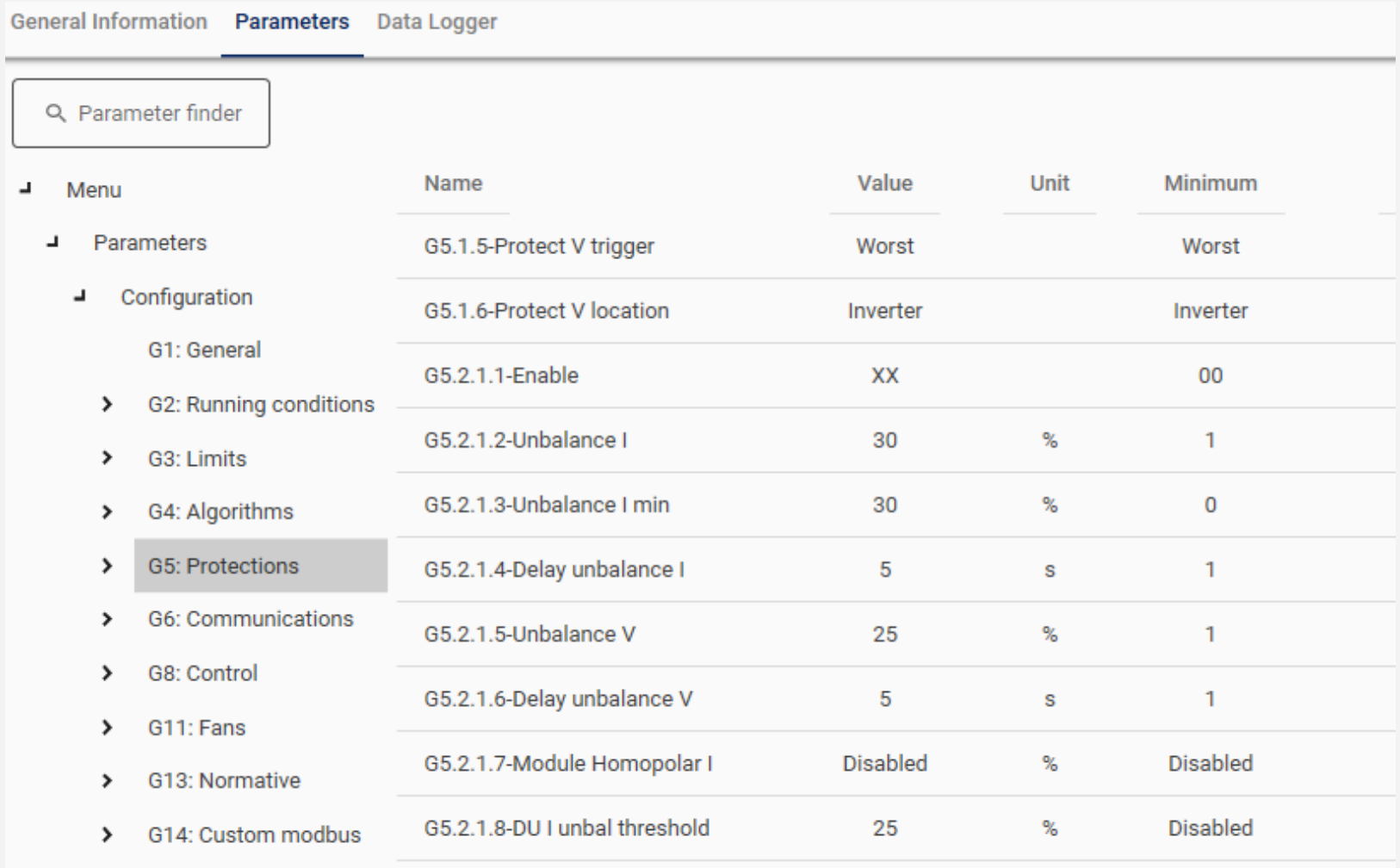
- Interfaces with GTAO card
- Measures ac current
- Measures dc current

Pulse Distributor Board

- Interfaces with GTDI card
- Uses UCM GTDI interface
- Fires pulses to UCM



PARAMETERS TO PROGRAM CONTROLLER



CONTROLLER GENERAL INFORMATION

Communication Connected | Date/Time 5/2/2023 1:46:23 PM | Status ON | Fault NO FLT | Warning OVLAC | Power (kW) 1024 | Selector status On

▶ Start | ■ Stop | Reset

General Information | Parameters | Data Logger

Solar Inverter Information

G3.1.1-P limit Discharge 100.00 %	G8.1.1-P control mode Pac	SV3.2.8-Q LV -1 kVAr	SV2.9-DC Voltage bus 1 1179.6 V	SV3.2.1-Grid voltage RS LV 644.9 V	SV1.6.4-Admission T° -31 °C
G3.1.2-Q limit 100.00 %	SV1.7.1-P control X00	SV3.2.9-S LV 1009 kVA	SV2.13-Dc Voltage extern 1 1194.1 V	SV3.2.2-Grid voltage ST LV 644.1 V	SV1.2.1-Start conditions all Yes
G3.1.3-P/Q priority Q	G8.1.2-Q control mode Q	SV3.2.10-Cos phi LV 1.000		SV3.2.3-Grid voltage TR LV 644.3 V	
	SV1.7.2-Q control 00X	SV3.2.12-Grid freq 59.976 Hz		SV3.2.4-Grid current I1 LV 918.0 A	
	G8.1.3-Pac reference 100.00 %			SV3.2.5-Grid current I2 LV 918.0 A	
				SV3.2.6-Grid current I3 LV 917.0 A	

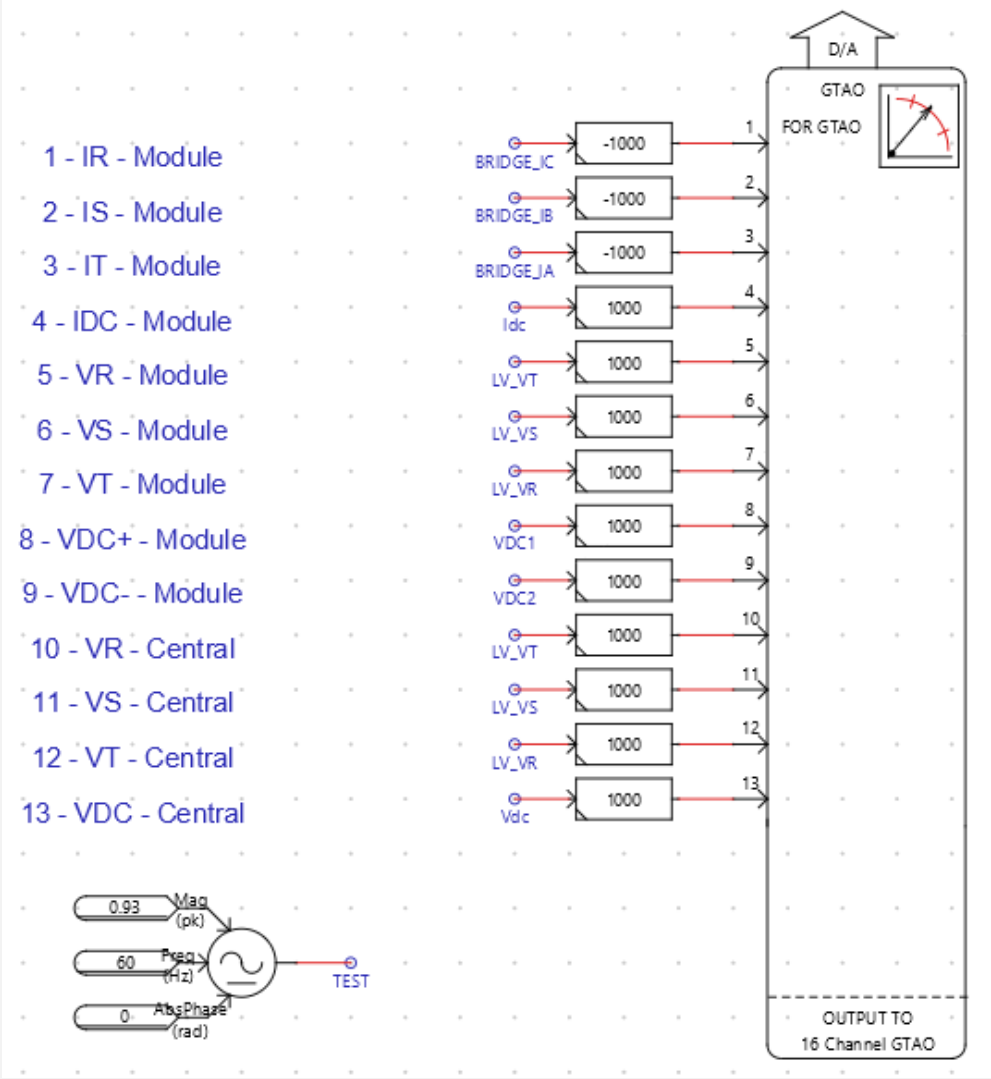
Modules Information

Module	Status	Ir (A)	Is (A)	It (A)	Idc (A)	Vdc + (V)	Vdc - (V)	Vdc (V)	P (kW)	IGBT max. T (°C)	Tr1 (°C)	Tr2 (°C)	Tr3 (°C)	Ts1 (°C)	Ts2
1	Run	935	932	930	831	58.8	58.7	117.5	13343	212.19	212.19	203.19	203.19	212.19	203

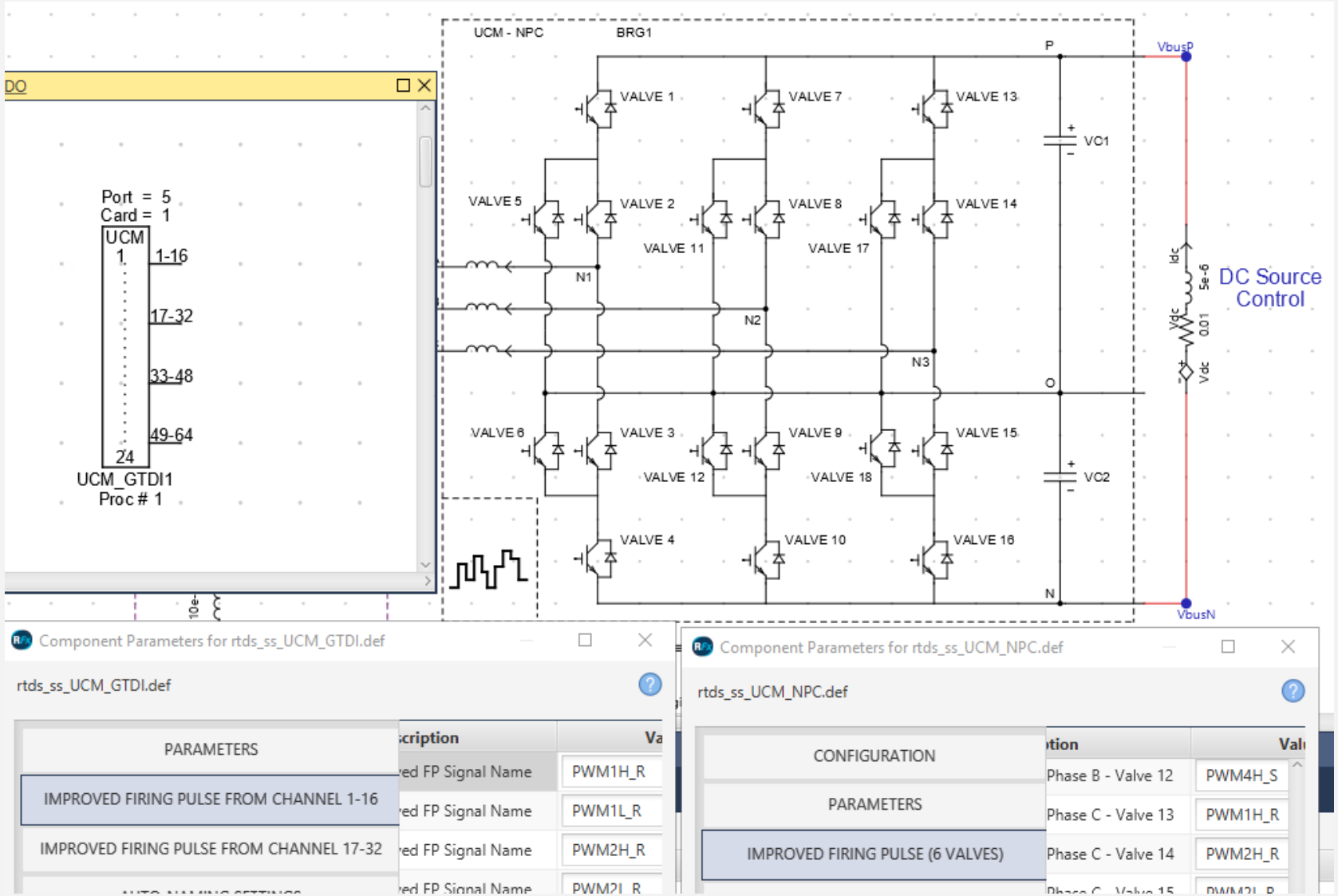
CONTROLLER VERIFICATION

GTAO Outputs

- Set inputs to known nominal values
- Measured voltages at the board
- Adjusted scaling factors appropriately
- Replaced test signals with actual



GTDI
UCM



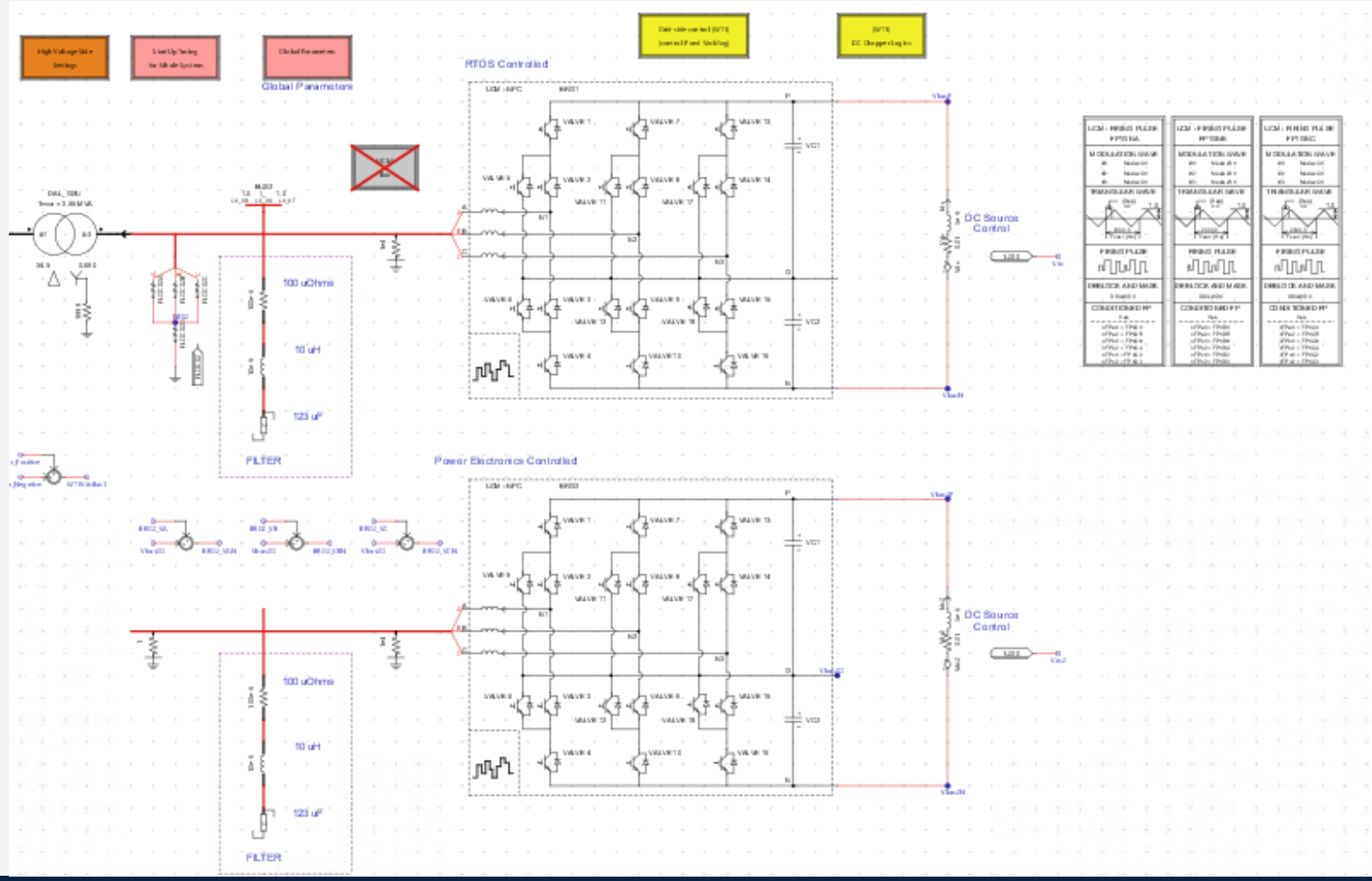
UCM

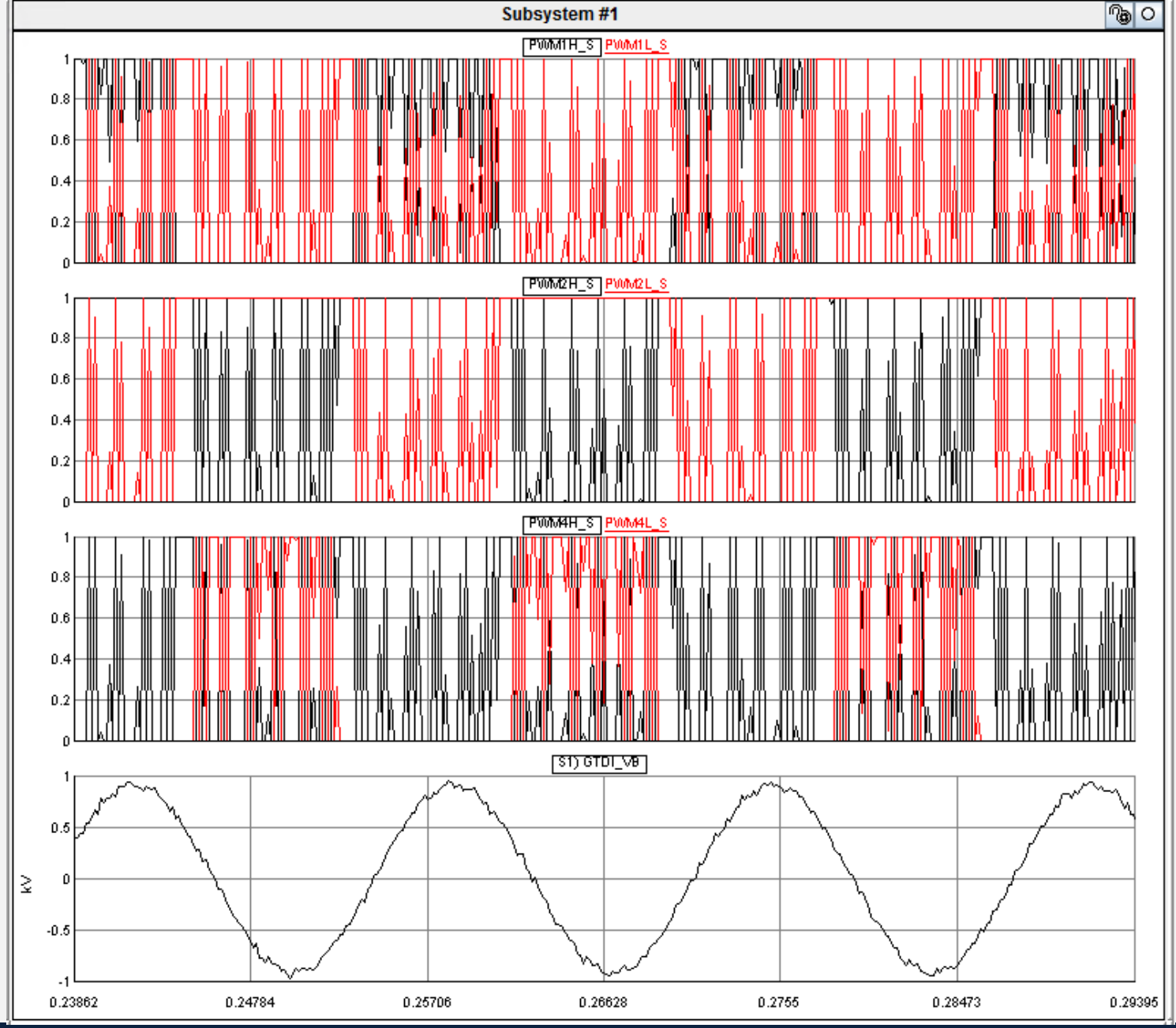
Pulse
Names

CONTROLLER VERIFICATION

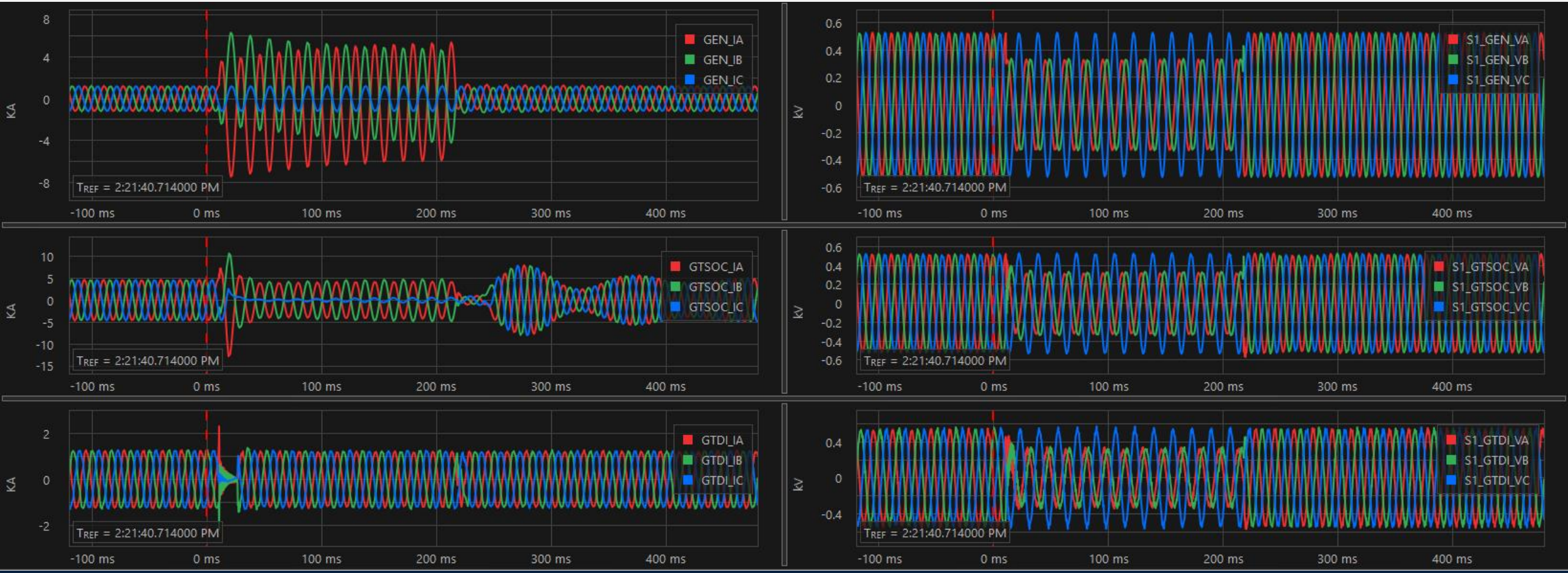
GTDI Inputs

- Ran controller in an open-loop
- Used RTDS-provided firing pulse generator
- Verified signals were getting to control board
- Verified proper phase sequence

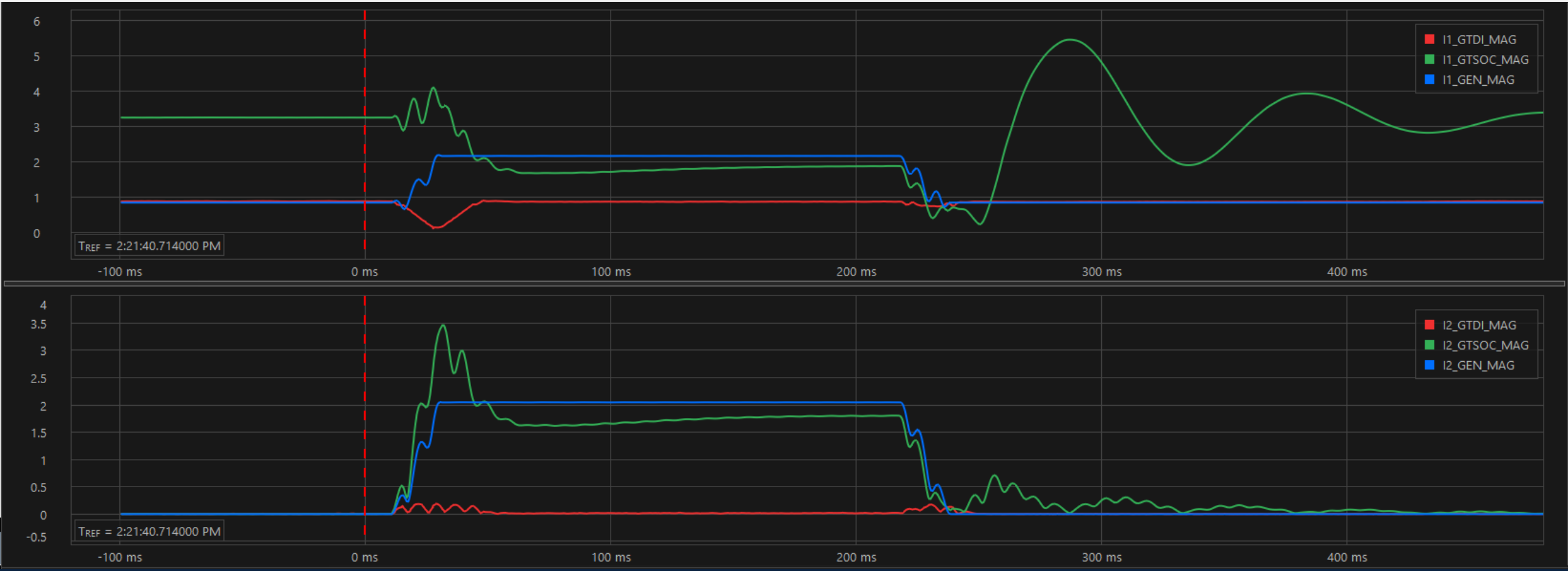



Subsystem #1
PWM1H_S
PWM1L_S
PWM2H_S
PWM2L_S
PWM4H_S
PWM4L_S
S1) GTDI_VB
kV
1
0.8
0.6
0.4
0.2
0
0.5
-0.5
-1
0.23862
0.24784
0.25706
0.26628
0.2755
0.28473
0.29395

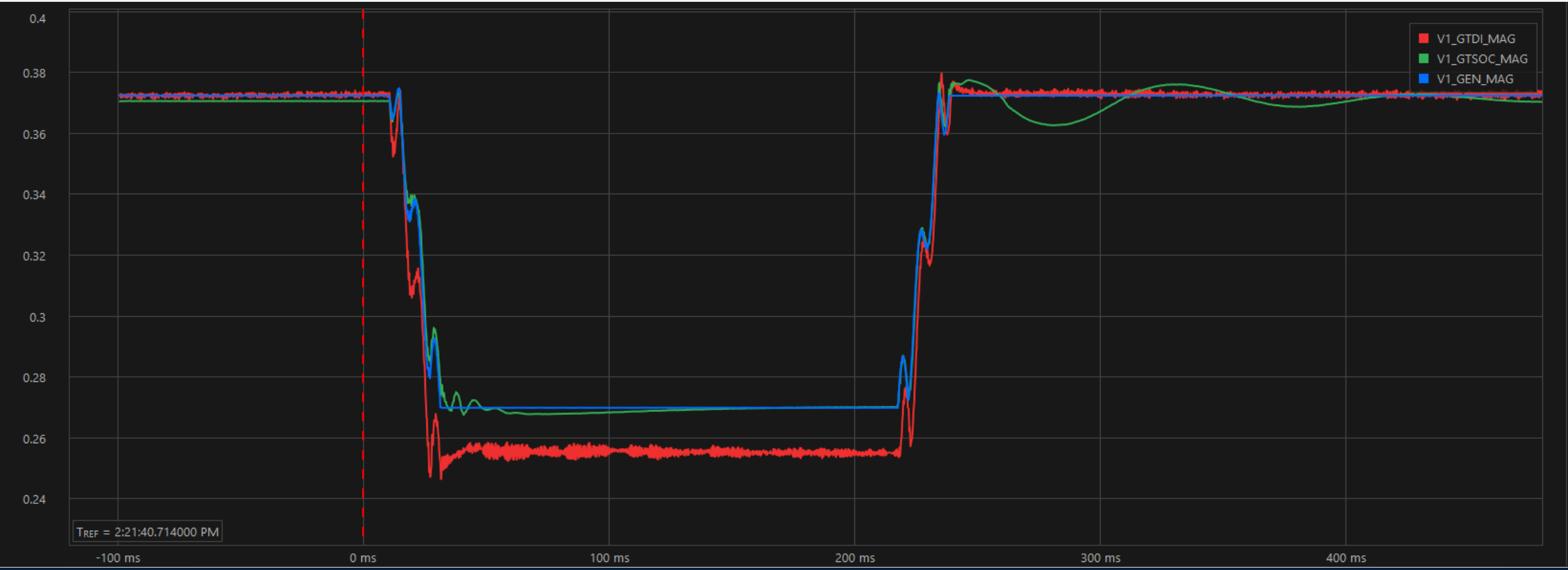
SINGLE-LINE-TO-GROUND FAULT PHASE VOLTAGES AND CURRENTS



SINGLE-LINE-TO-GROUND FAULT
I1 AND I2 SEQUENCE CURRENT MAGNITUDES

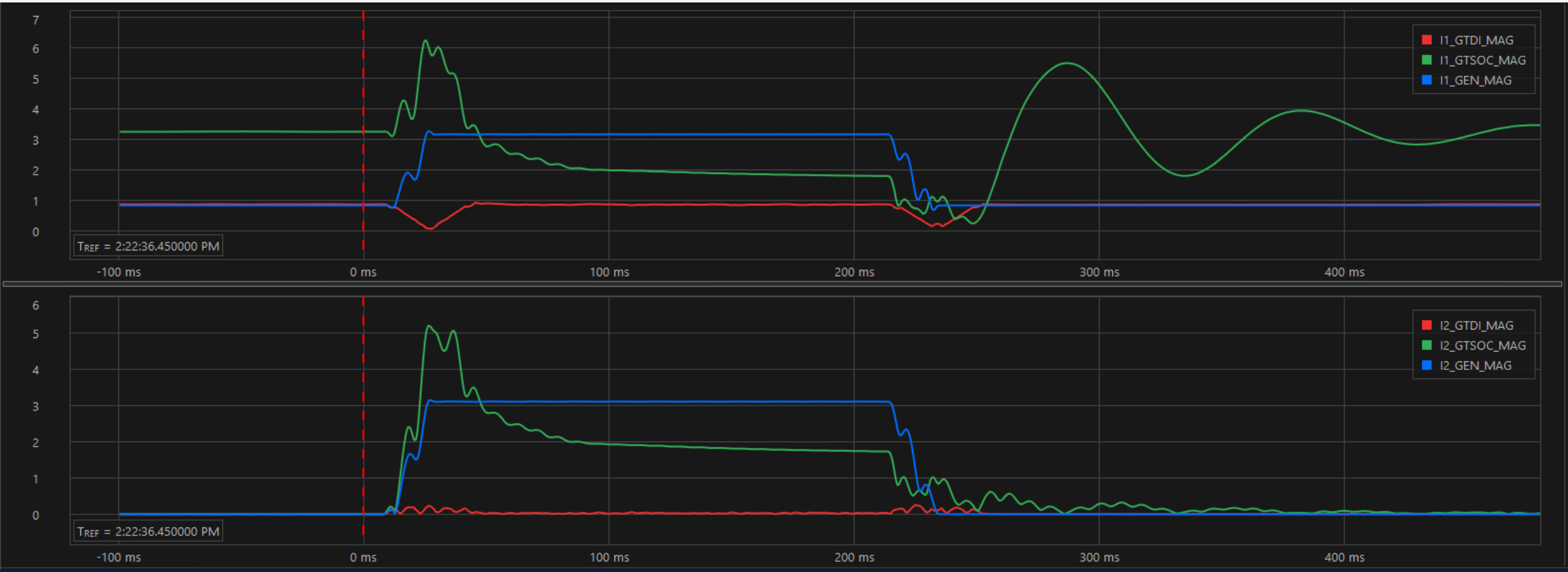


SINGLE-LINE-TO-GROUND FAULT
V1 SEQUENCE VOLTAGE MAGNITUDE

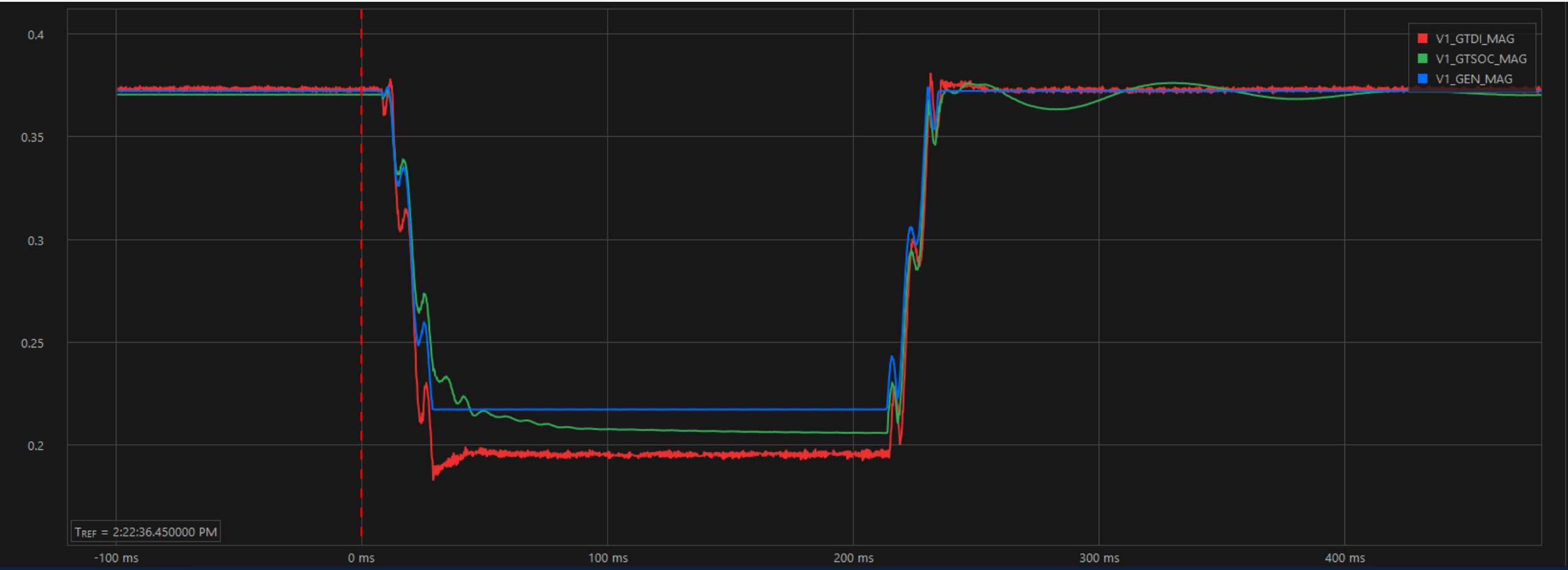


PHASE-TO-PHASE FAULT
PHASE VOLTAGES AND CURRENTS

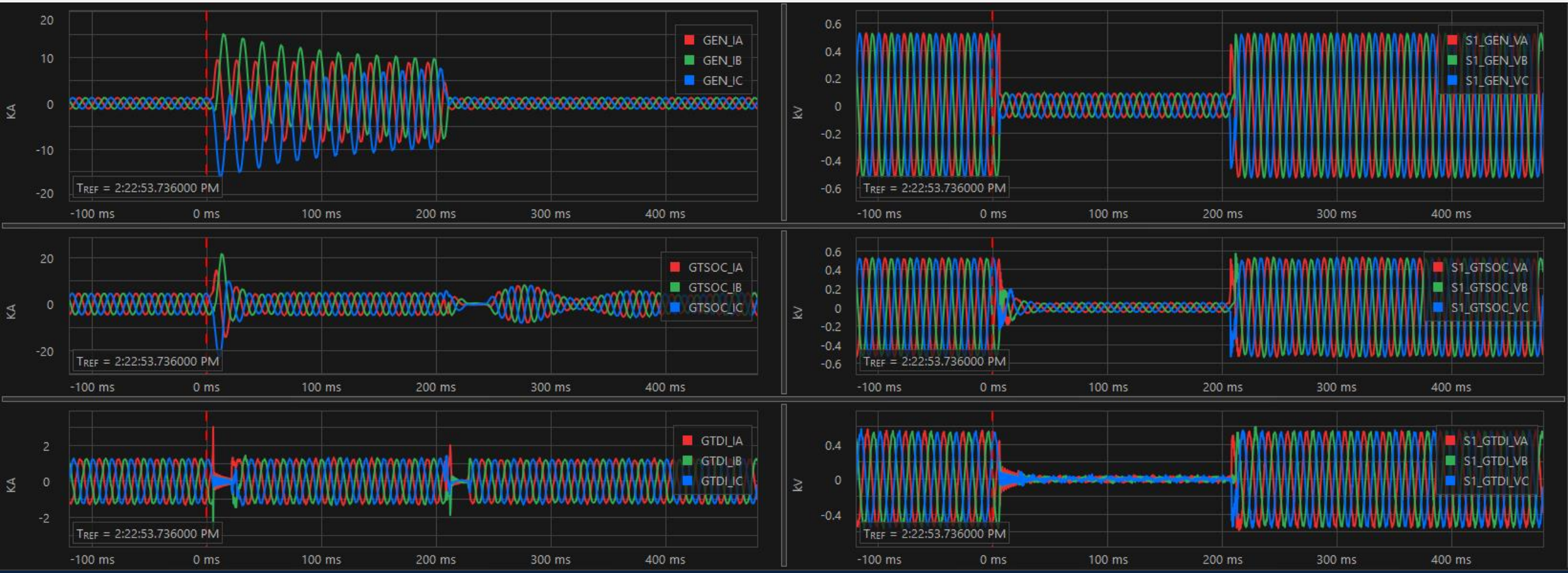
PHASE-TO-PHASE FAULT
I1 AND I2 SEQUENCE CURRENT MAGNITUDES



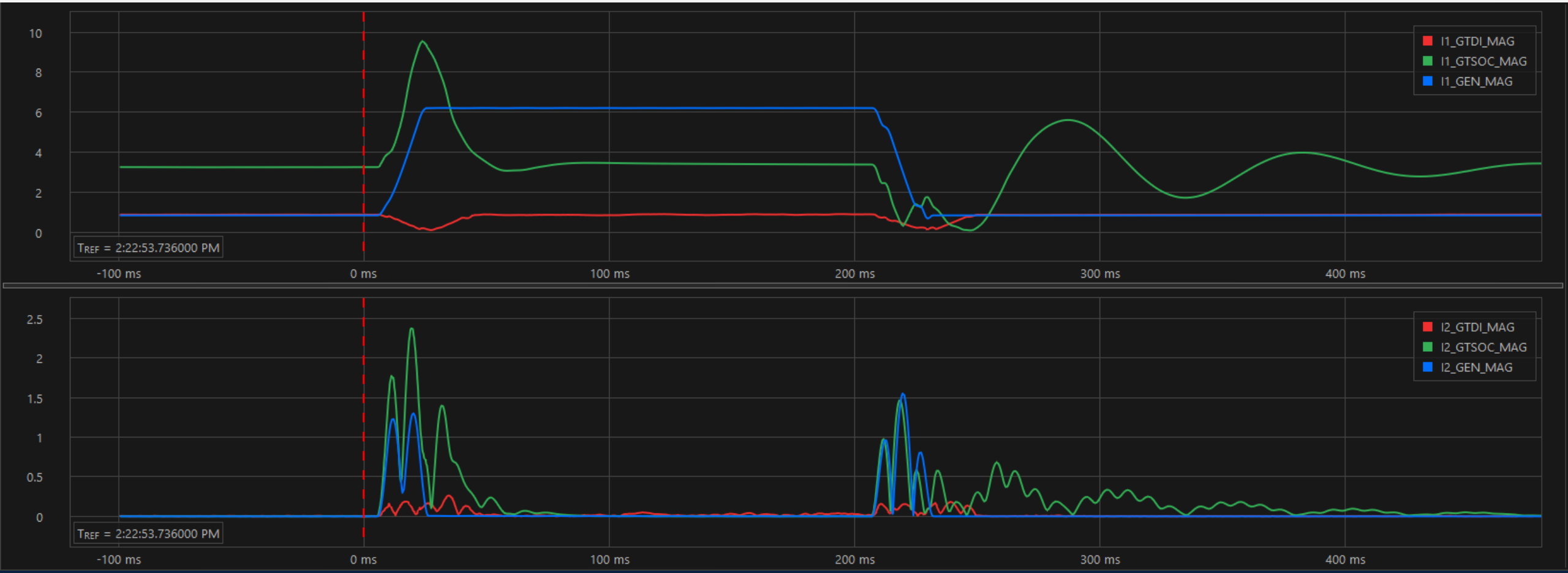
PHASE-TO-PHASE FAULT
V1 SEQUENCE VOLTAGE MAGNITUDE



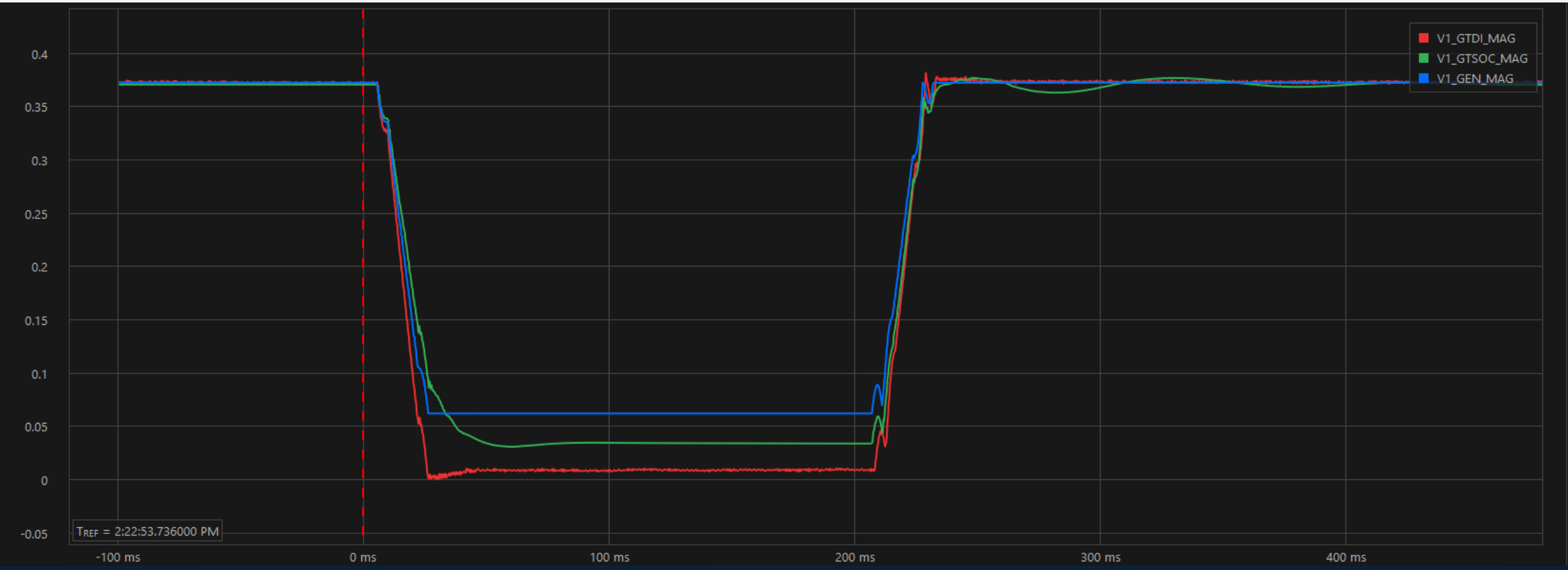
THREE-PHASE FAULT
PHASE VOLTAGES AND CURRENTS



THREE-PHASE FAULT
I1 AND I2 SEQUENCE CURRENT MAGNITUDES



THREE-PHASE FAULT
V1 SEQUENCE VOLTAGE MAGNITUDE



CONCLUSION

- Inverter-based resources do not perform the same as conventional sources
- Sequence components, required for relays, behave erratically
- Two methods are available to more accurately reproduce inverter behavior
  - GTSOC UCM
  - GTDI UCM
- Tested applications with manufacturer firmware and settings
  - GTSOC UCM with a datacenter
  - GTDI UCM for an extra-high-voltage (EHV) intertie