What's The Rush 2.0

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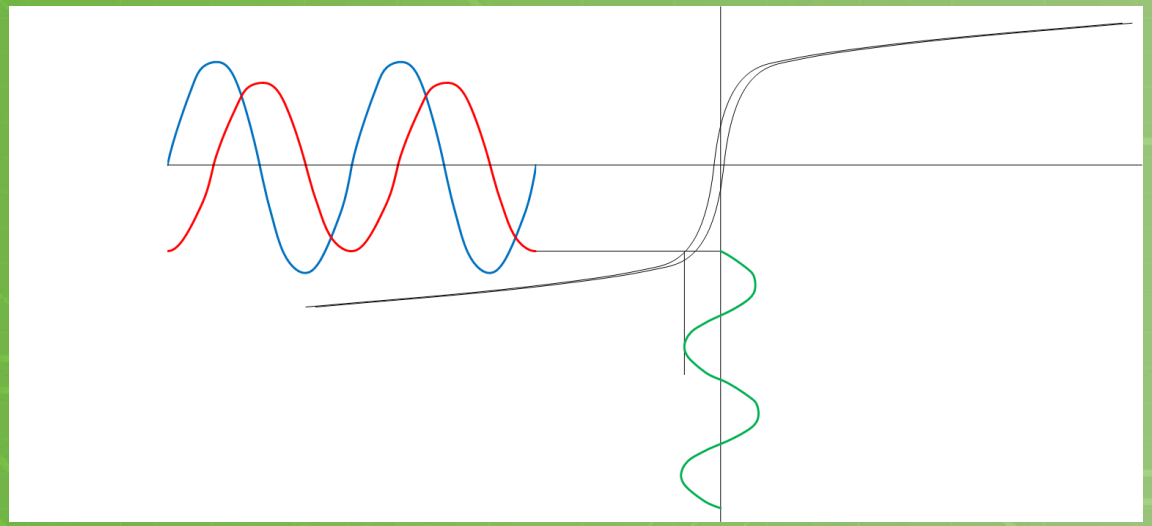
What's the Rush 1.0

Can IBR's lead to transformer relay misoperation?

Transformer Inrush



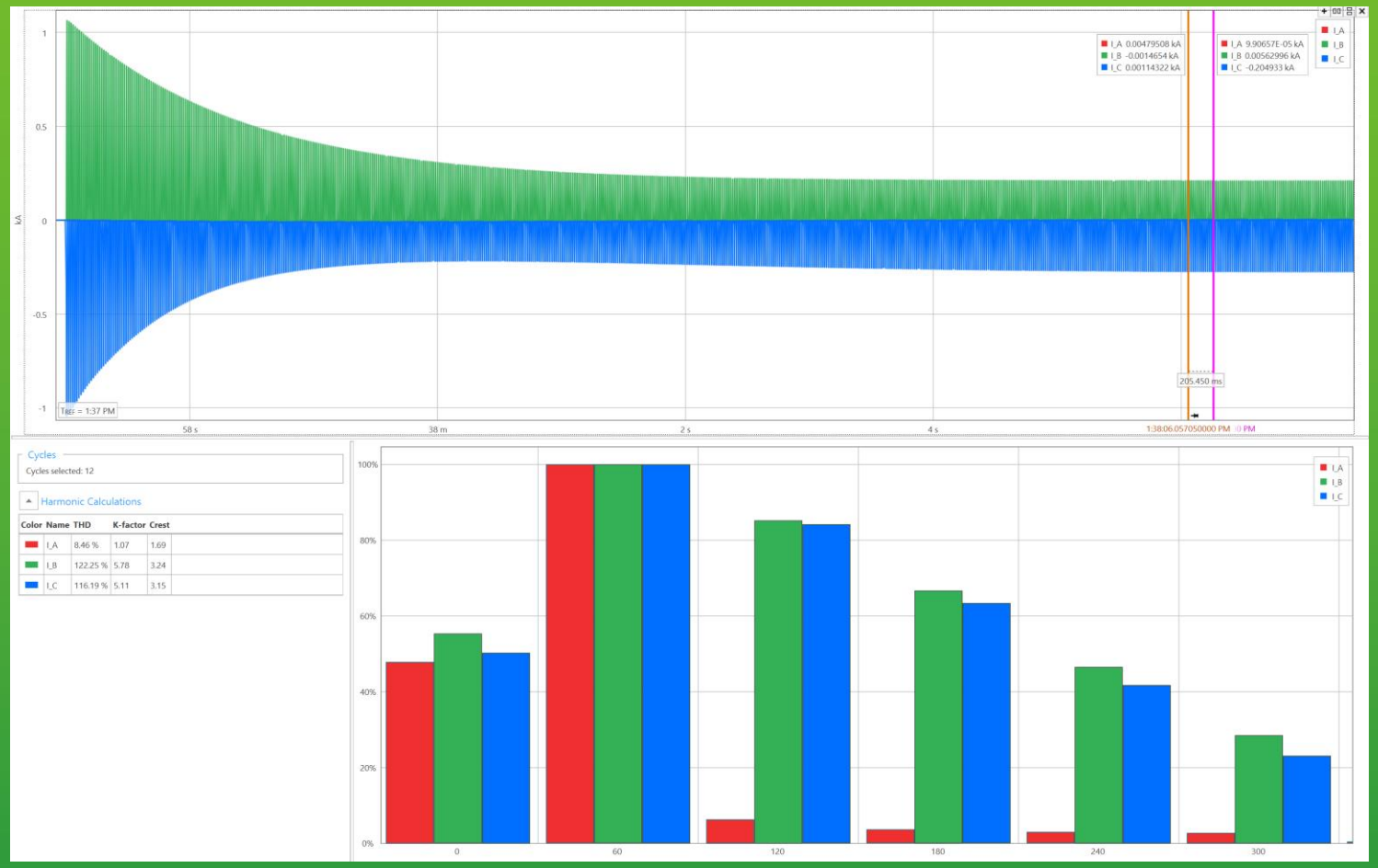
Rotating Machines

- 2nd Harmonic
- 4th Harmonic
- Up to 12x Rated Current

Conventional Relay Protection
(Using 2nd, 4th, and/or 5th Harmonics)

- Harmonic Blocking
- Harmonic Restraint

WTR 1.0 Findings

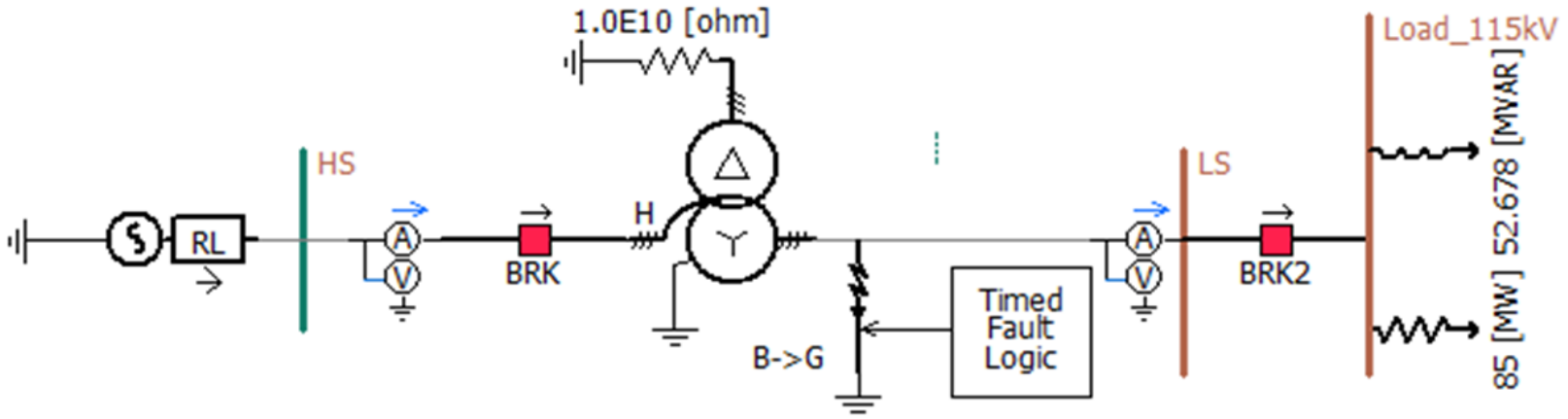


- Persistent 2nd harmonic content following inrush
- Potential blocking or restraint of the transformer diff. element during faults
- Possible “nuisance” trip during inrush

Data & Testing

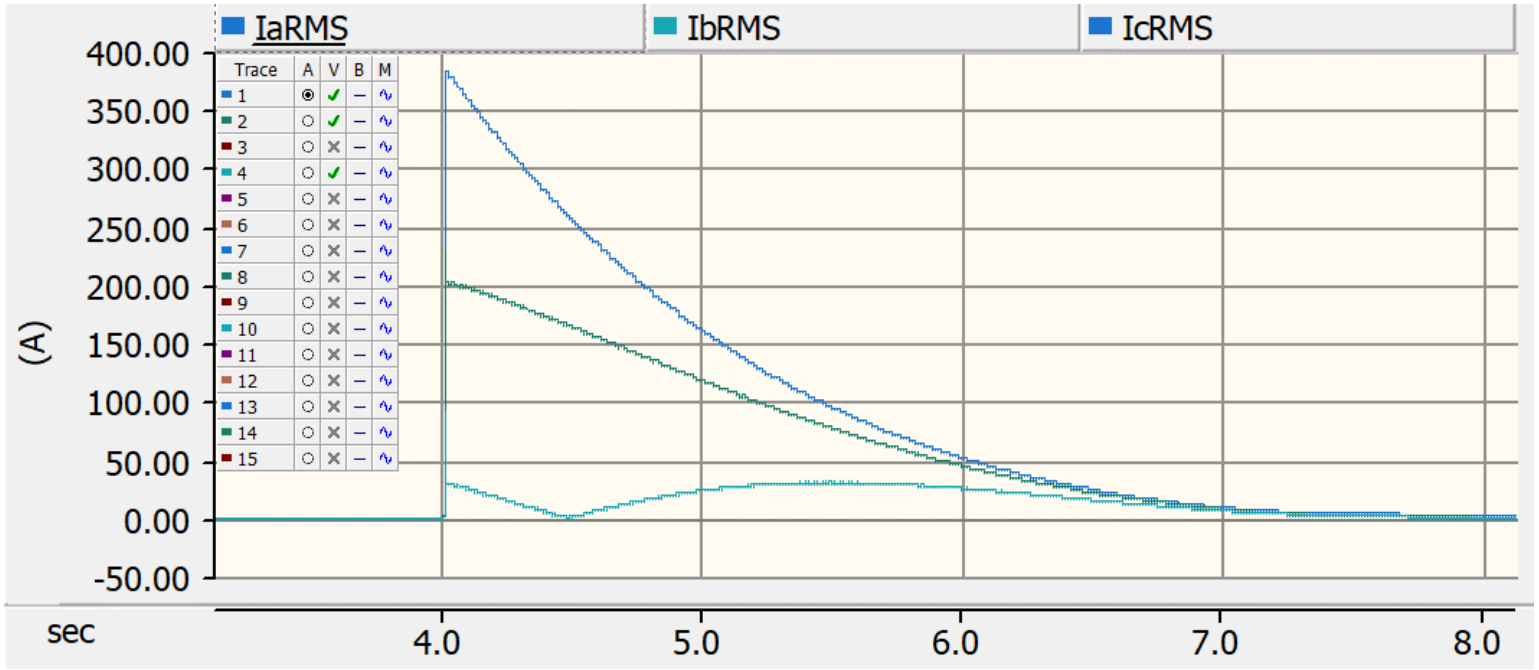
Synchronous Machine

System Model



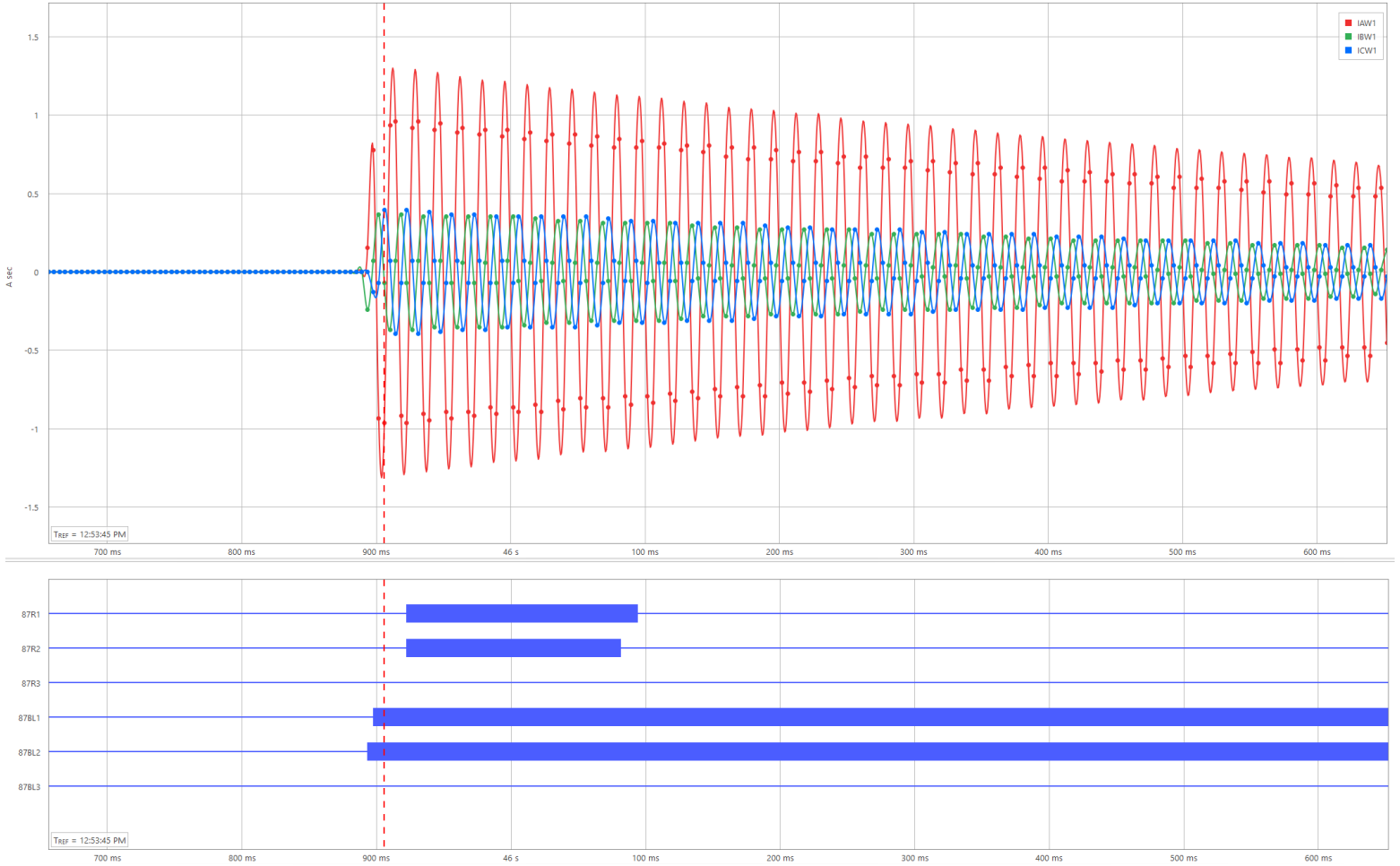
Synchronous Machine

Harmonic Content



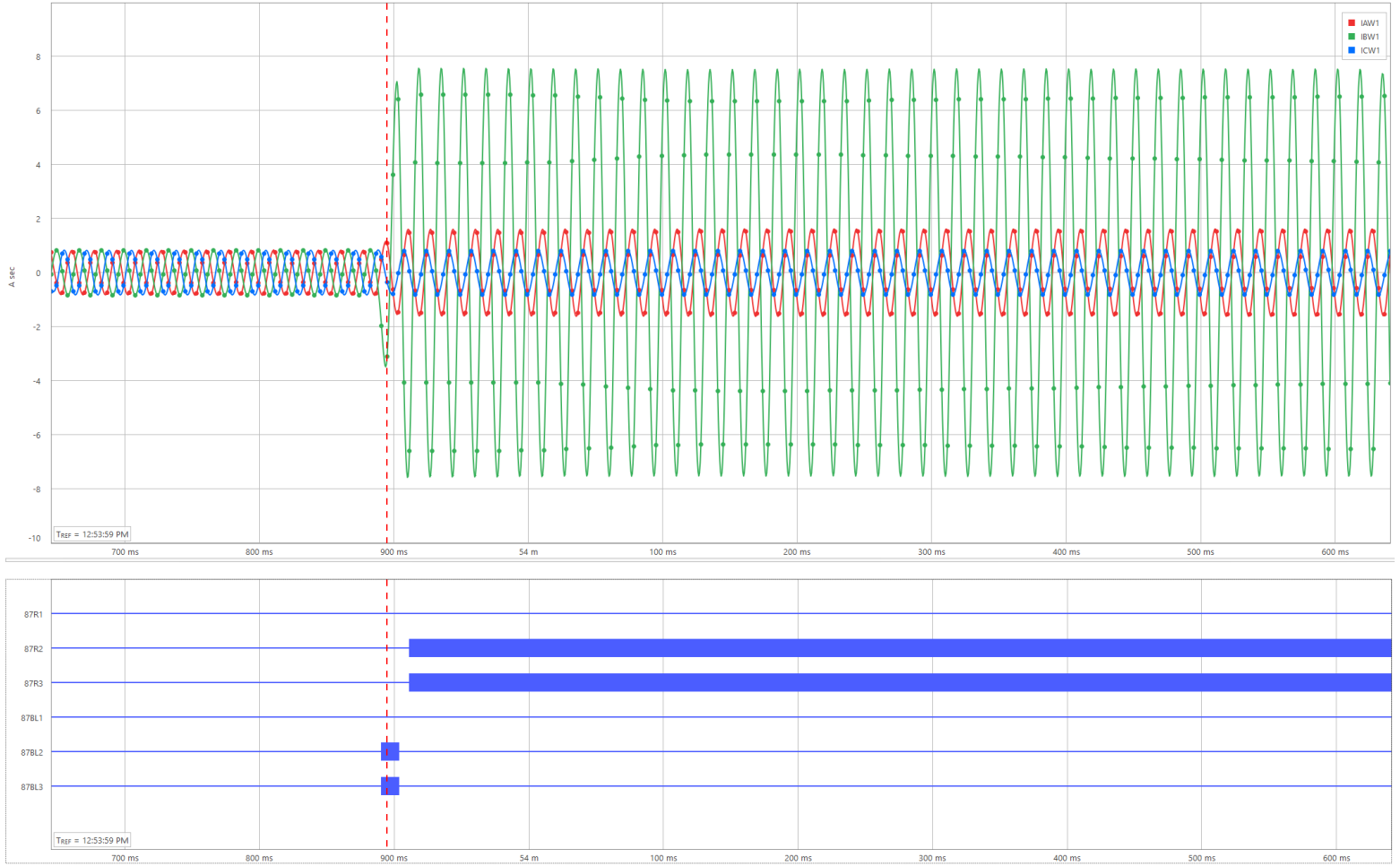
Synchronous Machine

Inrush Waveforms



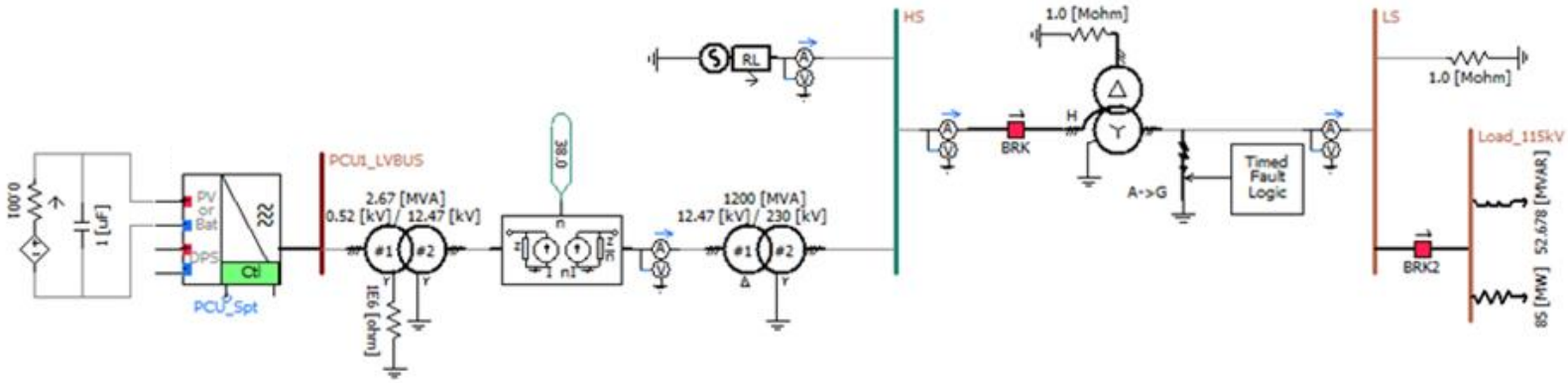
Synchronous Machine

Fault Waveform



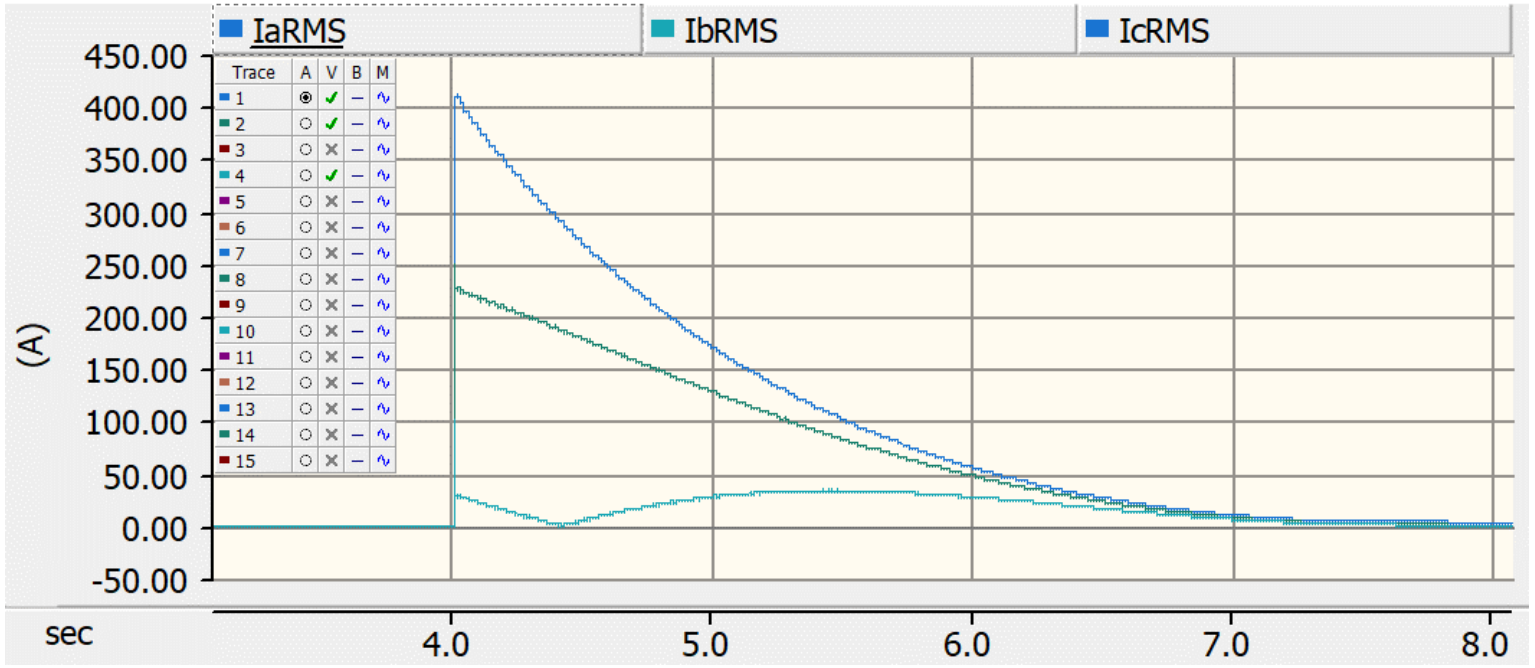
Grid-Following Inverter

System Model



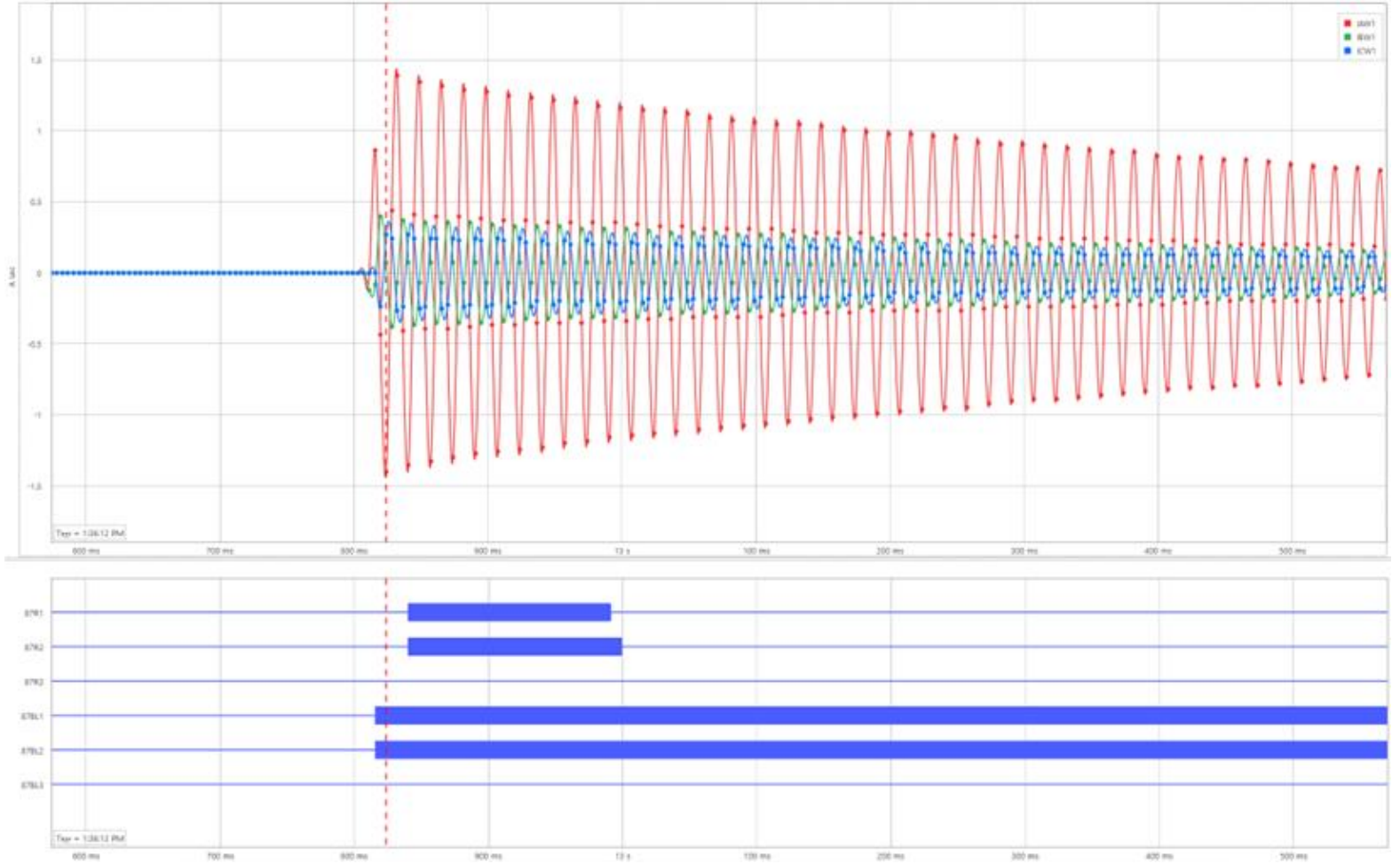
Grid-Following Inverter

Harmonic Content



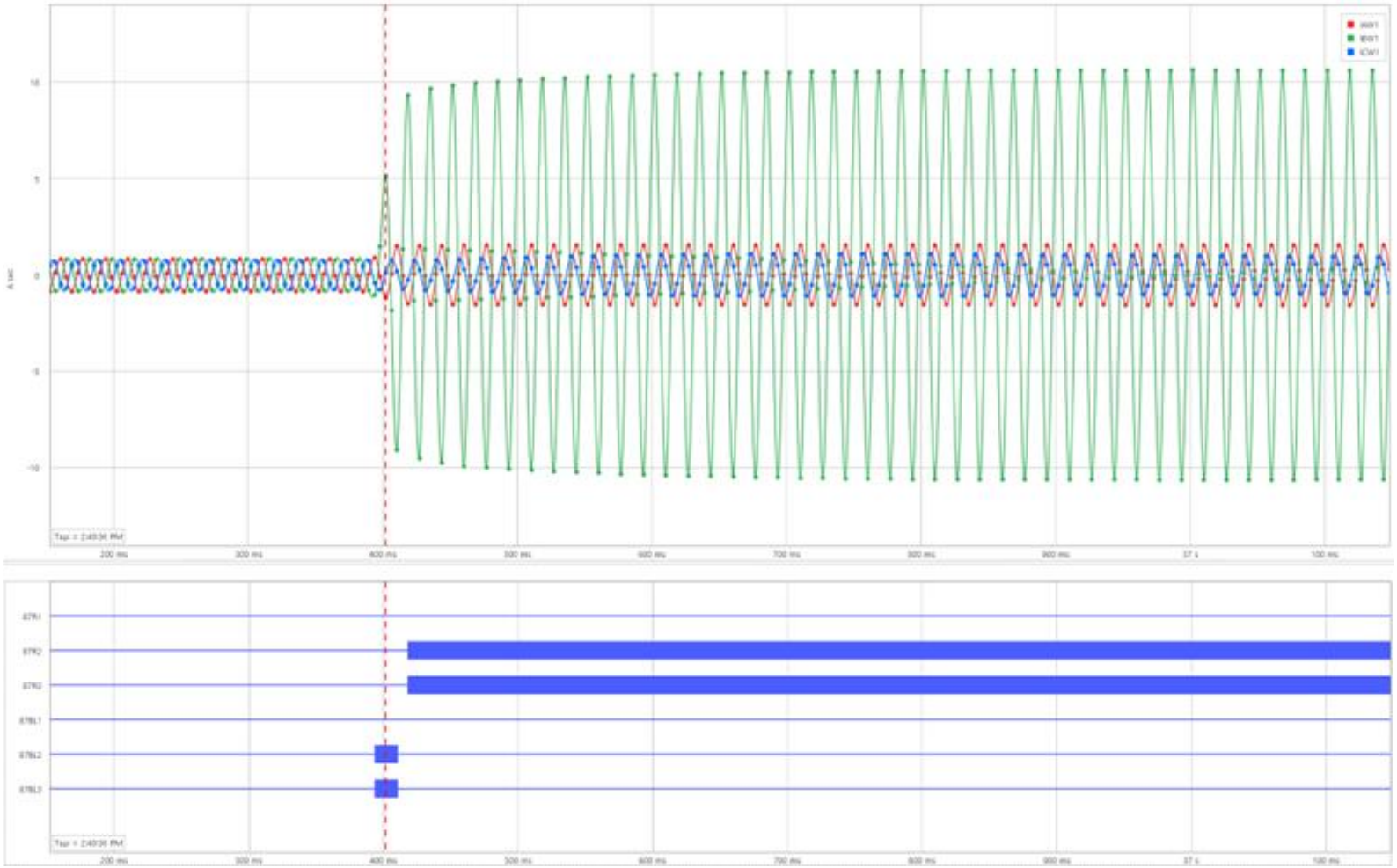
Grid-Following Inverter

Inrush Waveform



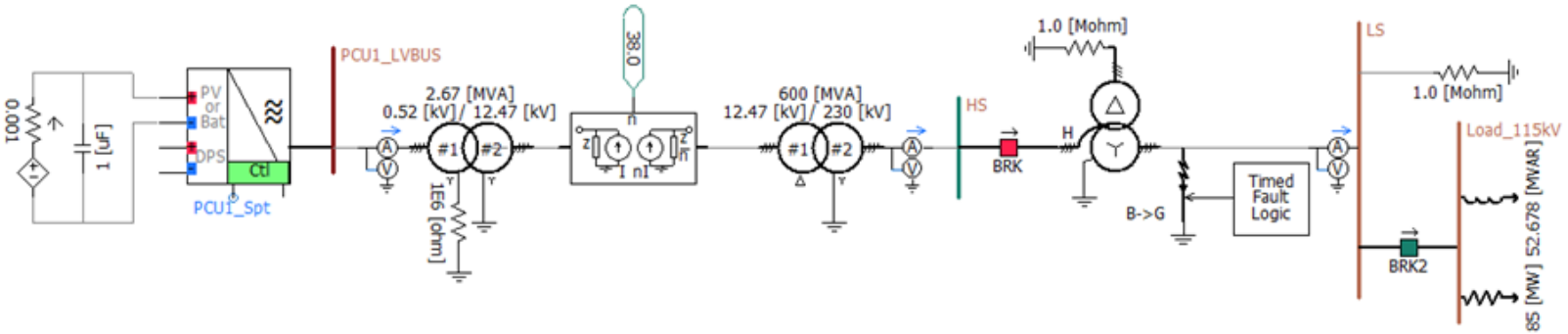
Grid-Following Inverter

Fault Waveform



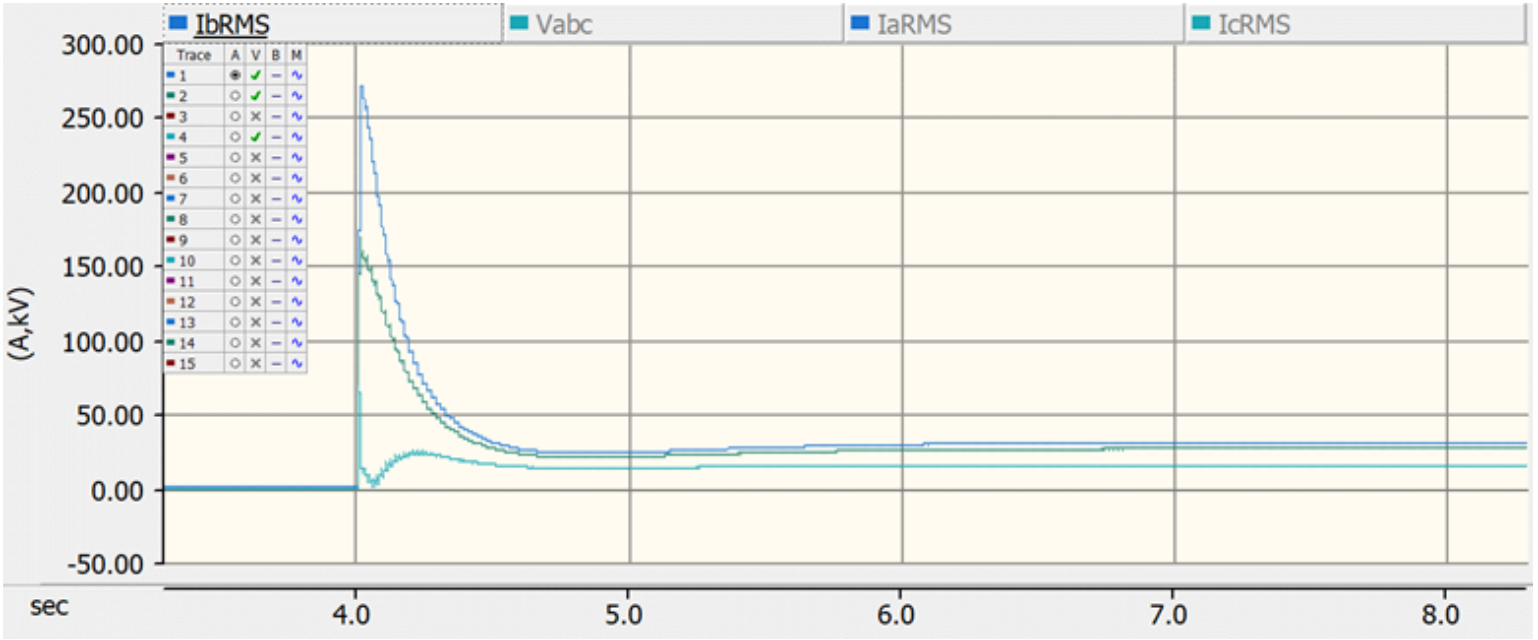
Grid-Forming Inverter (1 Inverter)

System Model



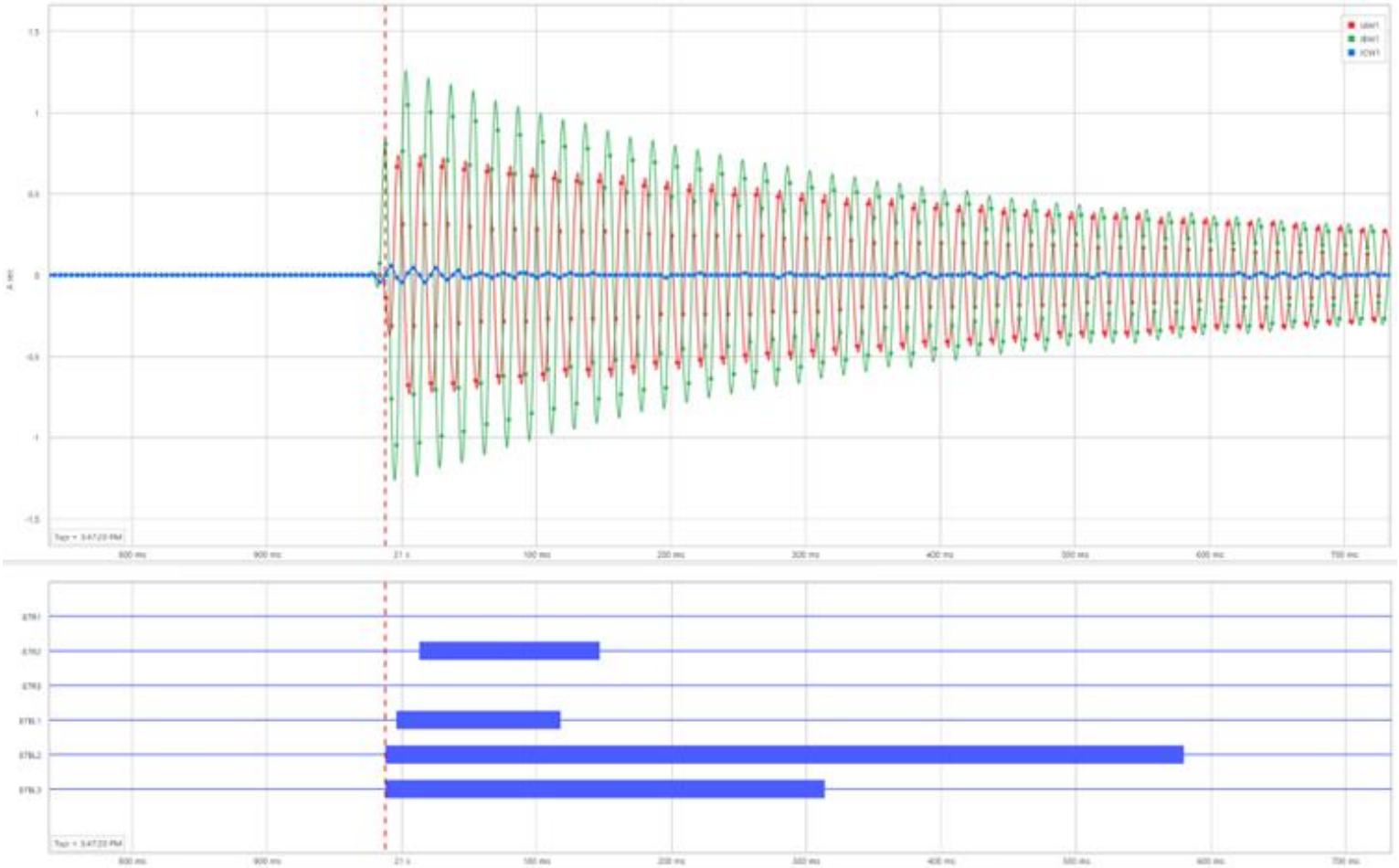
Grid-Forming Inverter (1 Inverter)

Harmonic Content



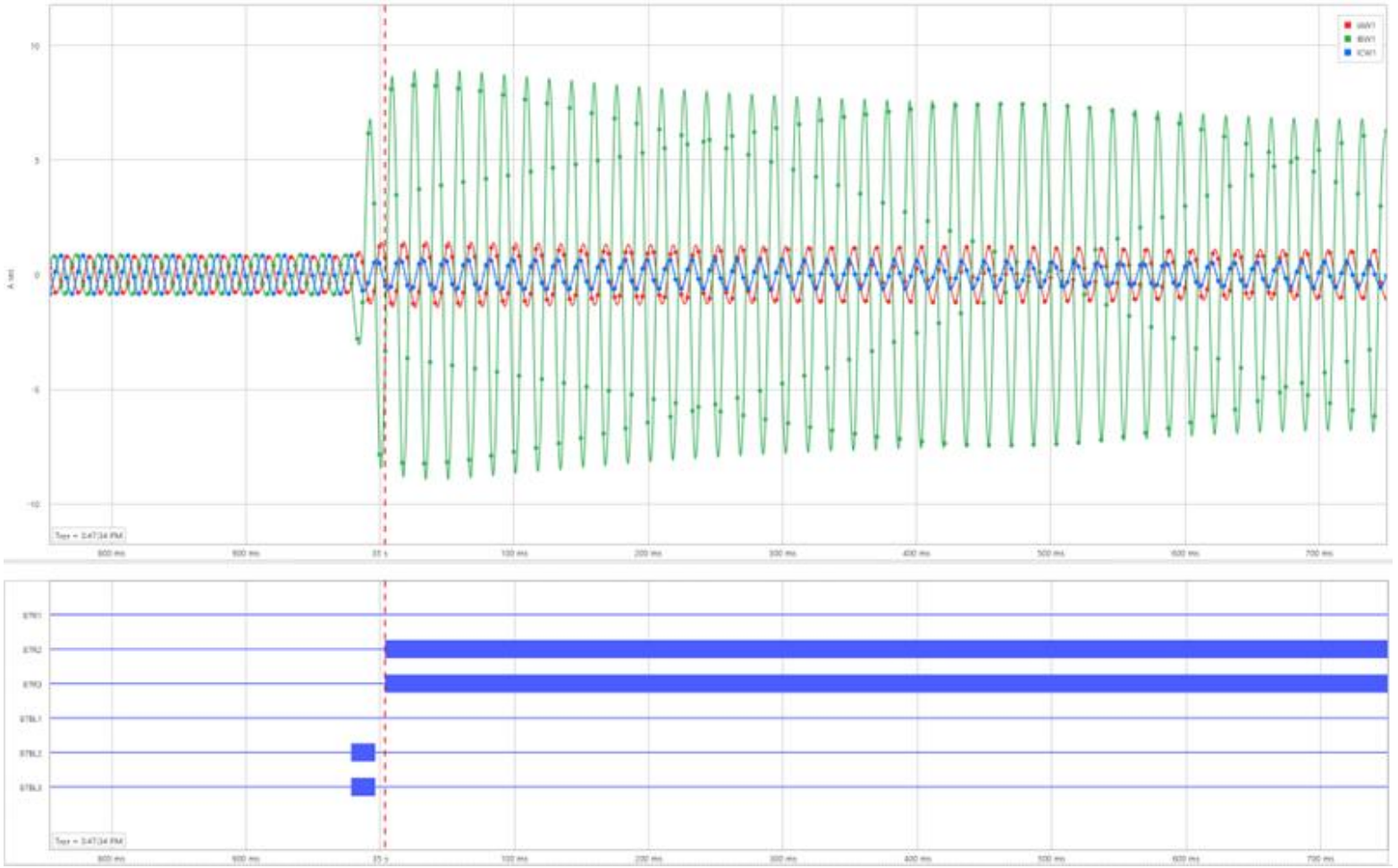
Grid-Forming Inverter (1 Inverter)

Inrush Waveform



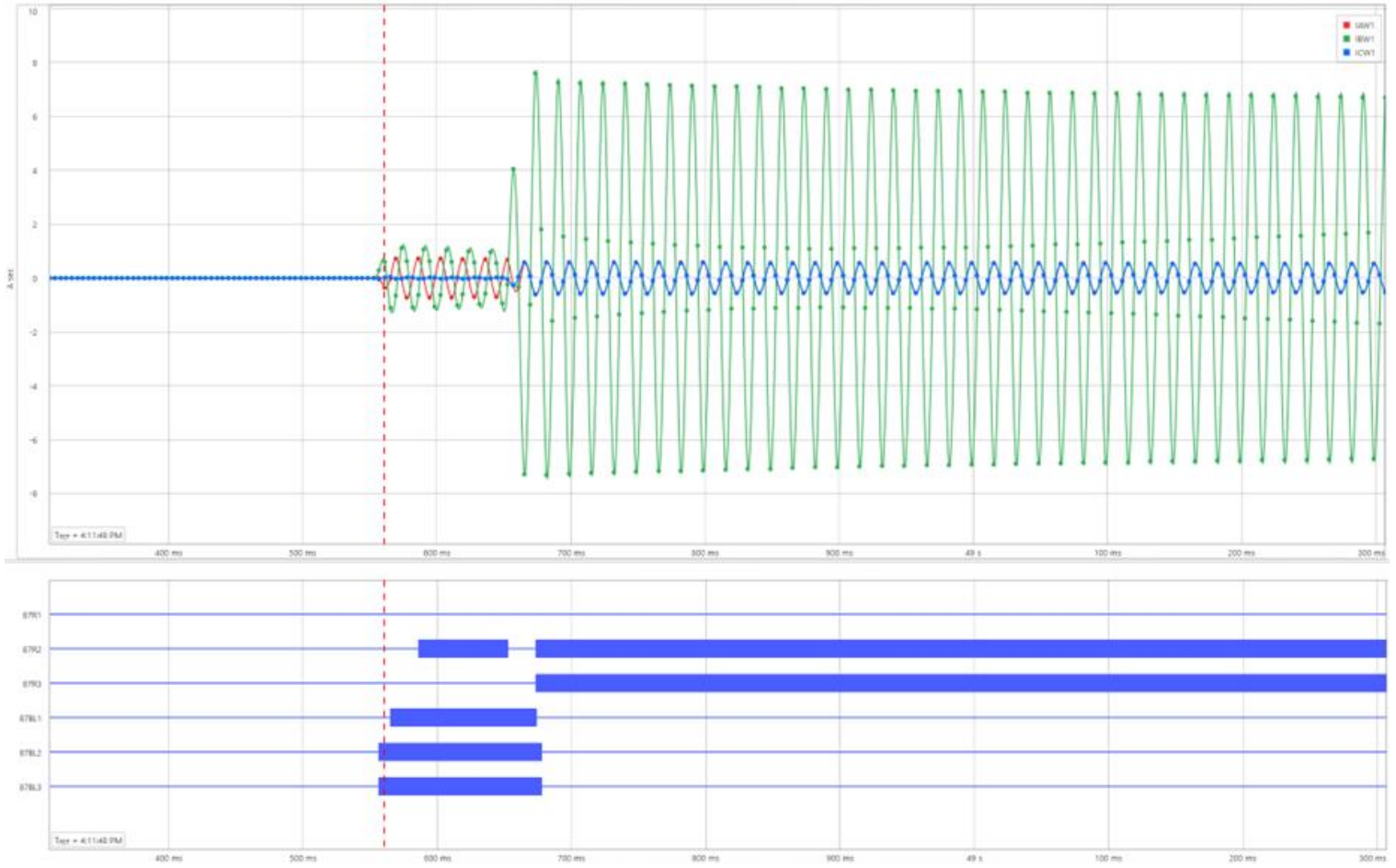
Grid-Forming Inverter (1 Inverter)

Fault Waveform



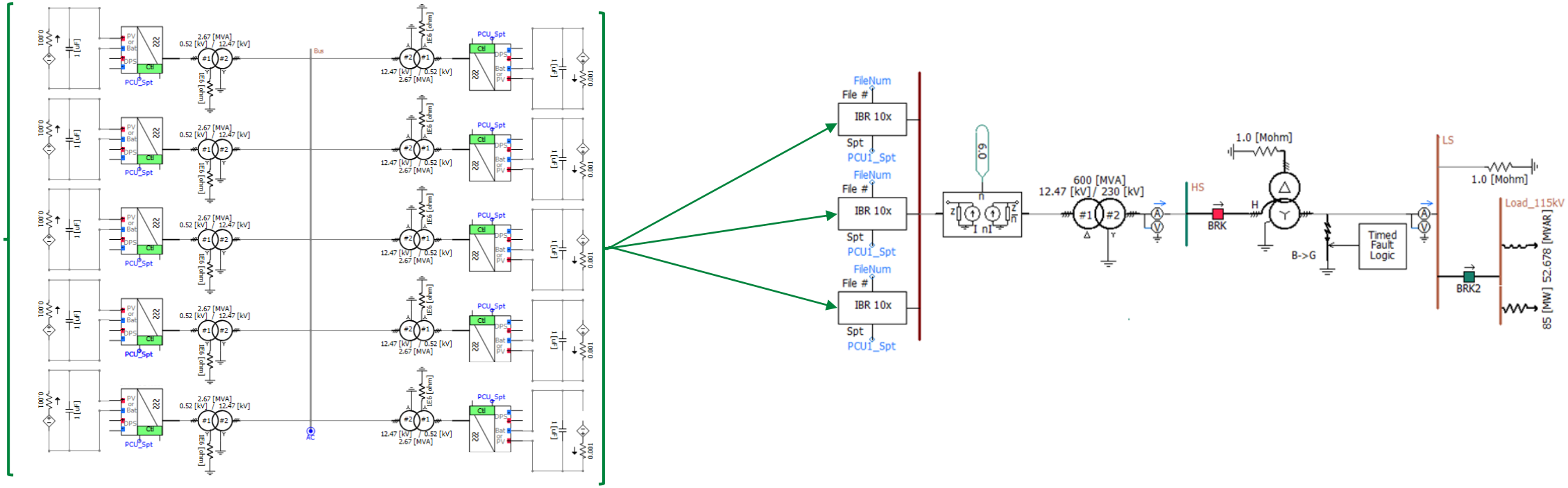
Grid-Forming Inverter (1 Inverter)

Fault During Inrush Waveforms



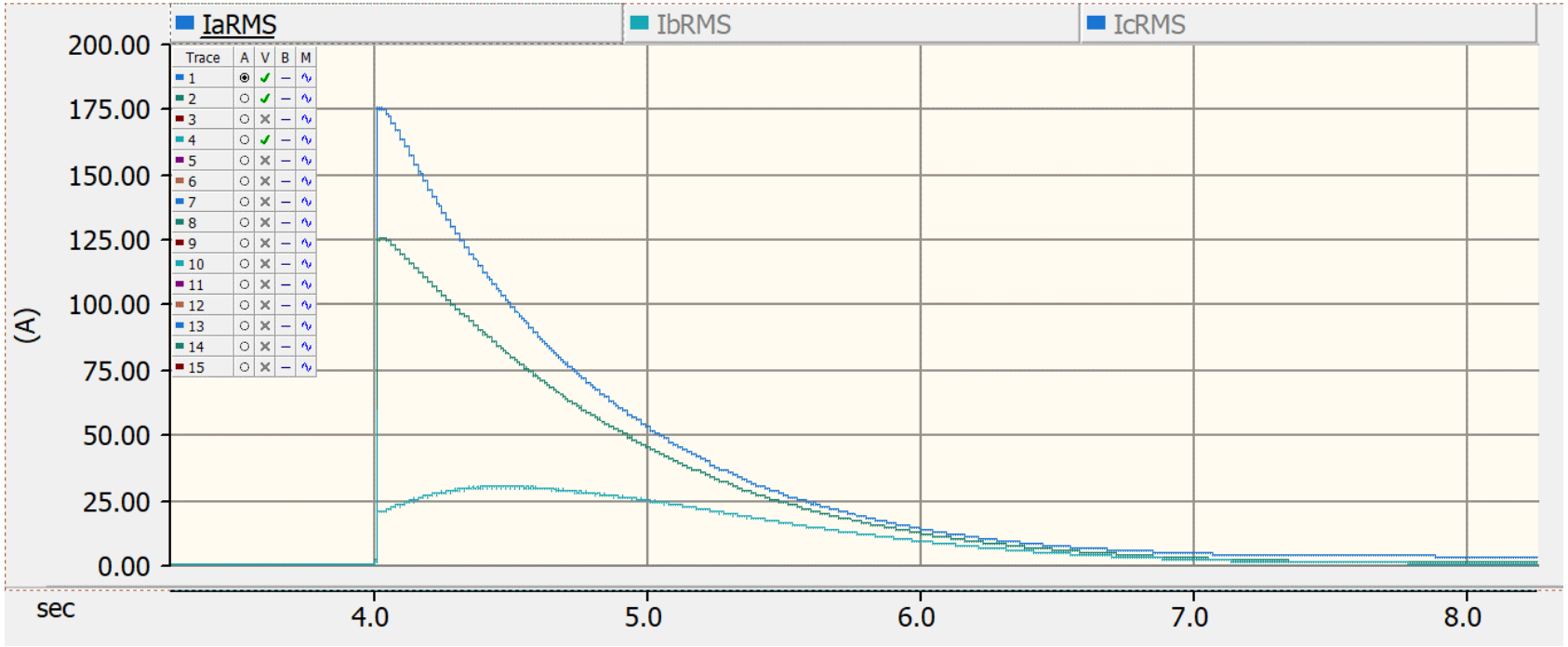
Grid-Forming Inverter (30 Inverters)

System Model



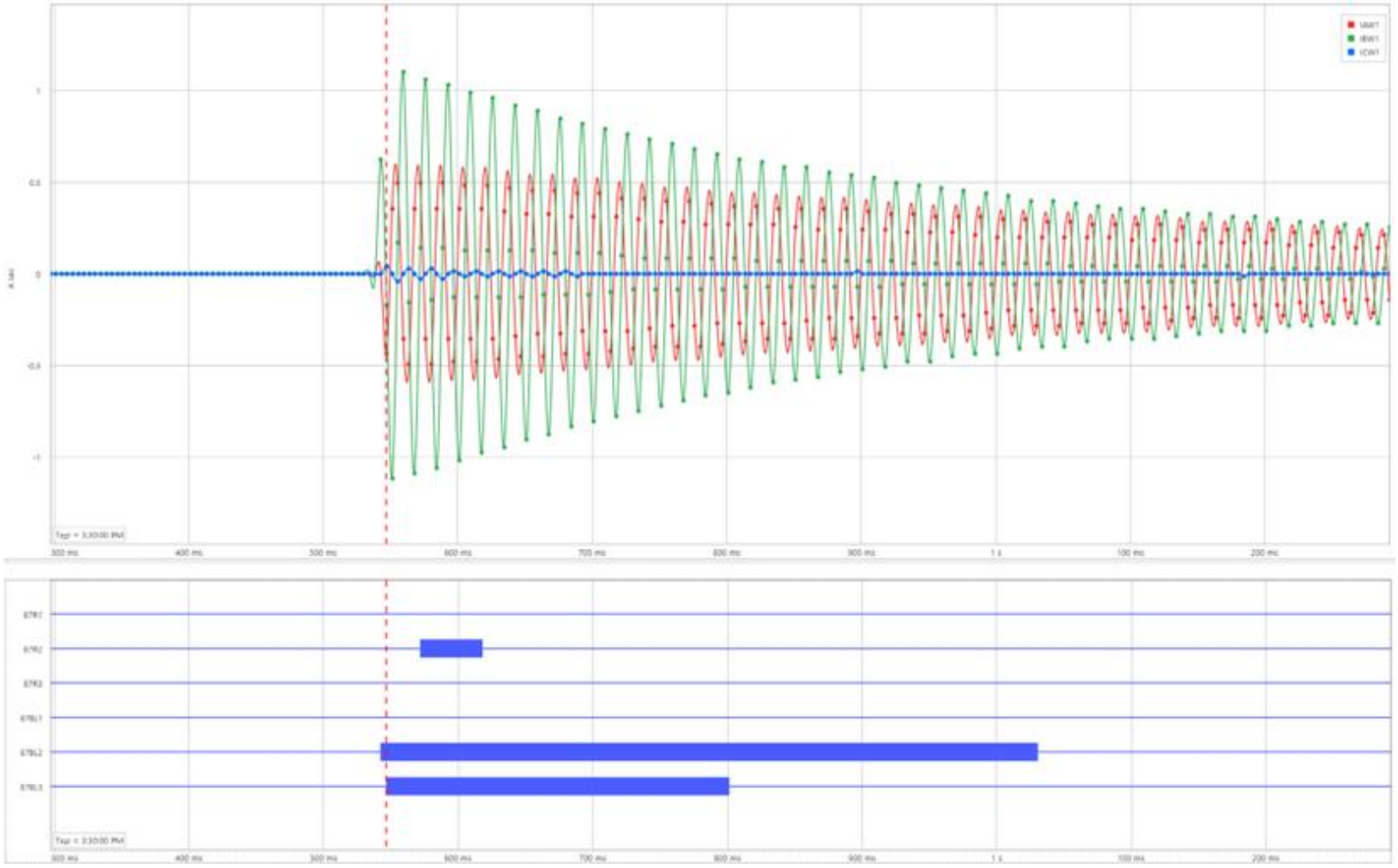
Grid-Forming Inverter (30 Inverters)

Harmonic Content



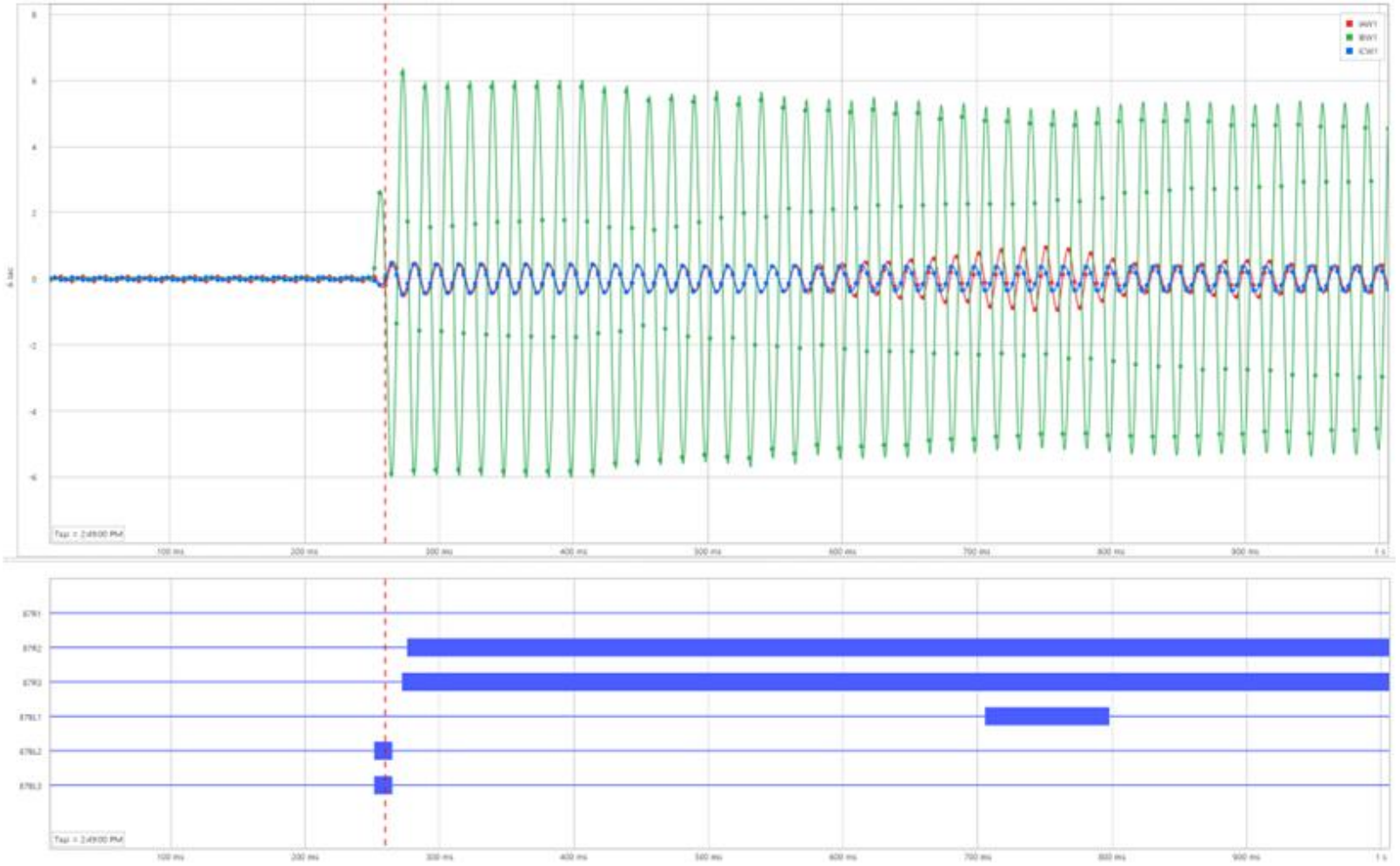
Grid-Forming Inverter (30 Inverters)

Inrush Waveform



Grid-Forming Inverter (30 Inverters)

Fault Waveform



RESULTS

Addressing WTR 1.0

- Conventional Protection Operates as Intended
- Residual Current Increases with IBR Penetration
- Grid-forming inverters decay faster than synchronous and grid-following

Future Potential Research

- Smaller Transformer (No Multiplier)
- Different Inverter Manufacturers
- Observe the effects of blocking 4^{th} and 5^{th} harmonics
- More Inverters Per Simulation

Questions?