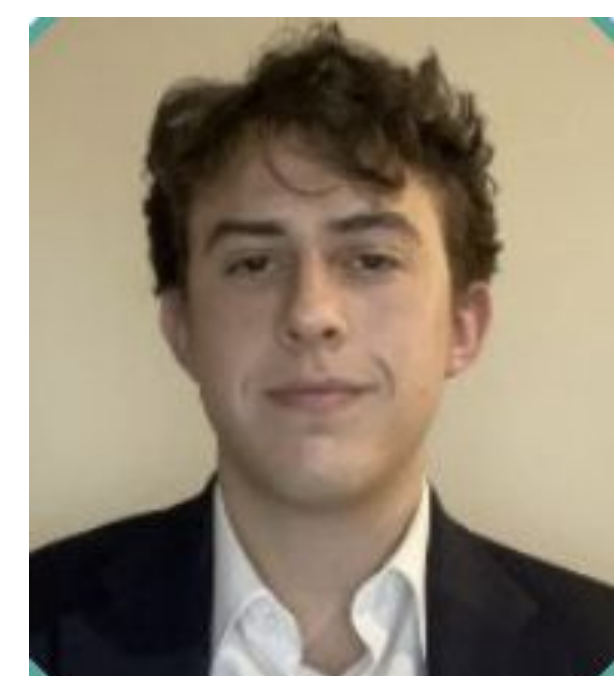


Project Overview

InverTech is a three-phase inverter developed and validated entirely in software using Simulink/Simscape Electrical to model and analyze realistic power system behavior. The system consists of three primary closed-loop control subsystems: a Phase-Locked Loop (PLL), d-q axis Proportional-Integral (PI) current controllers, and a DC bus voltage controller to produce a balanced three-phase output while maintaining grid synchronization.

The utilization of Simscape Electrical allowed for realistic and efficient testing under various operation conditions, including grid faults, frequency oscillations, and DC set point tracking. InverTech will aid Professor Tong Huang's research on grid security in the Texas electricity market, managed by the Electric Reliability Council of Texas (ERCOT), and is designed for future hardware implementation using the TI C2000 DSP platform.

Team Members



Nicholas Farcas - Team Lead
Electrical Engineer



Gonzalo Morales
Electrical Engineer



Ruth Burks
Electrical Engineer



Julius Harris
Electrical Engineer



David Ramos
Electrical Engineer

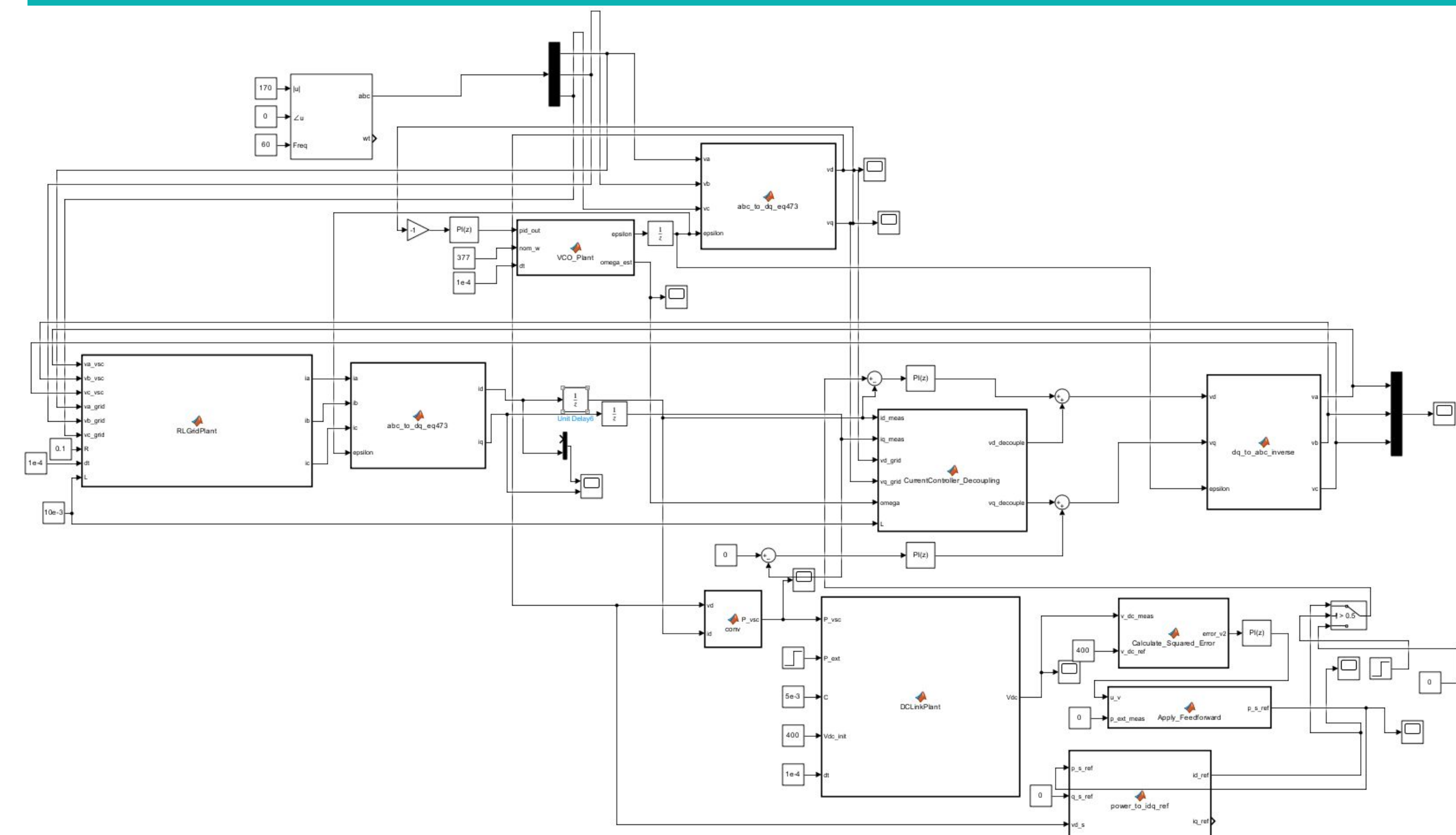
Motivation

- Safer way to test high-voltage inverter systems using matlab/simulink instead of physical hardware
- Reduces cost by validating control algorithms in simulation before building hardware
- Supports research in power grid reliability and stability
- Develops a system capable of grid synchronization and controlled power delivery
- Bridges the gap between simulation and real-world hardware implementation

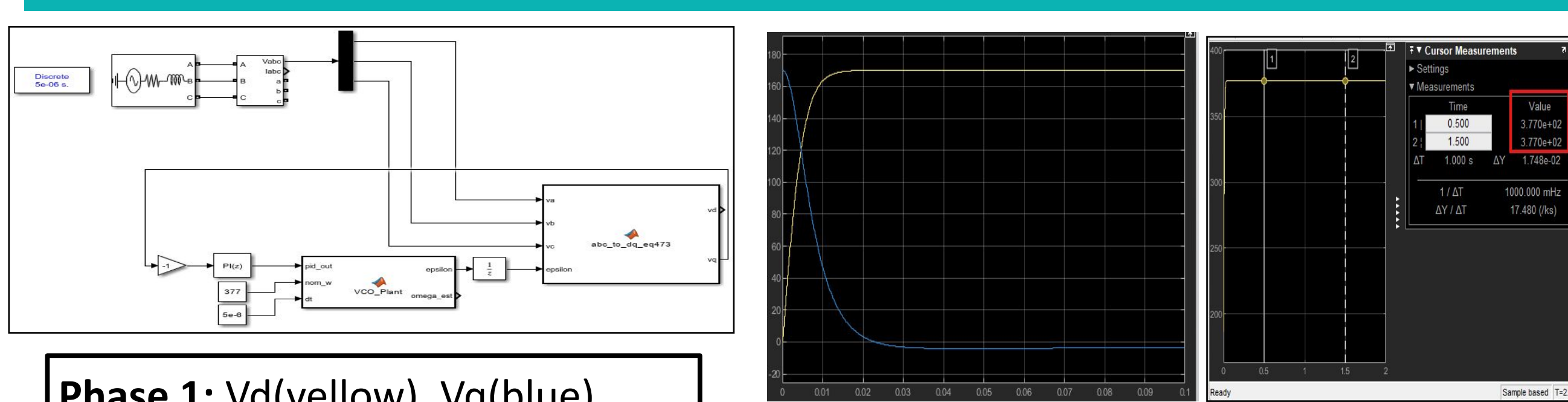
Acknowledgements

InverTech would like to give a special thank you to Dr. Tong Huang for his project sponsorship, technical guidance, and valuable insight throughout the design, integration and testing phases.

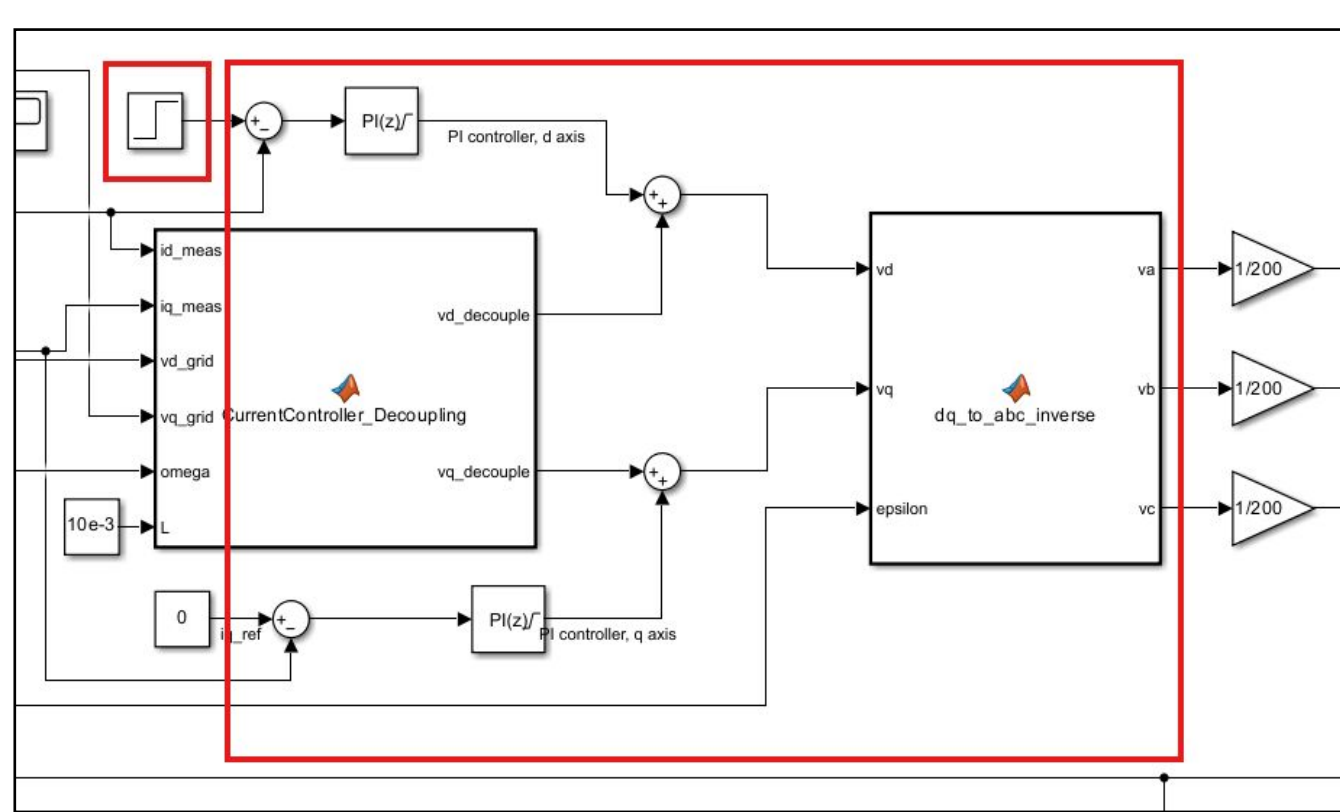
Final Model



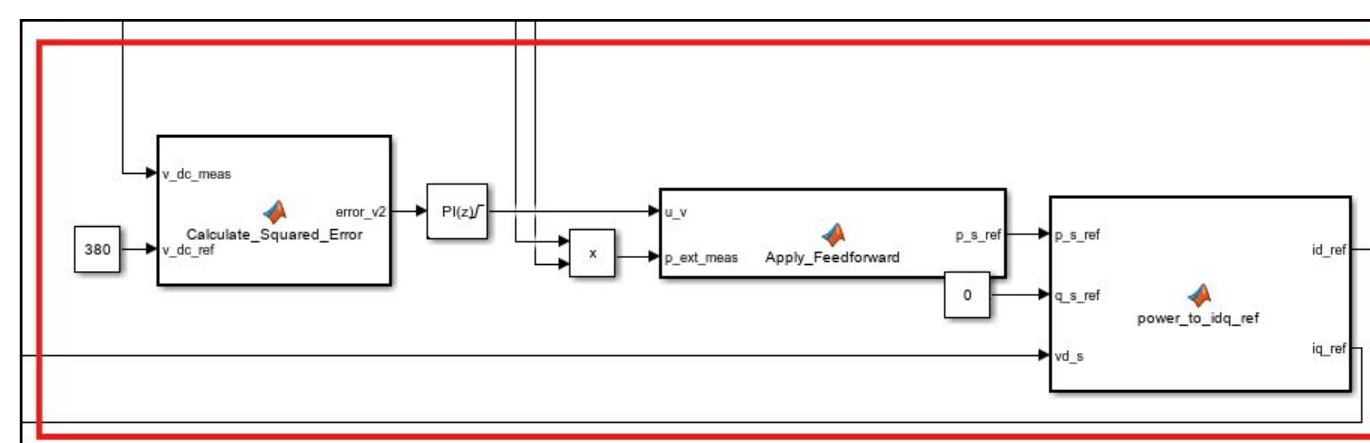
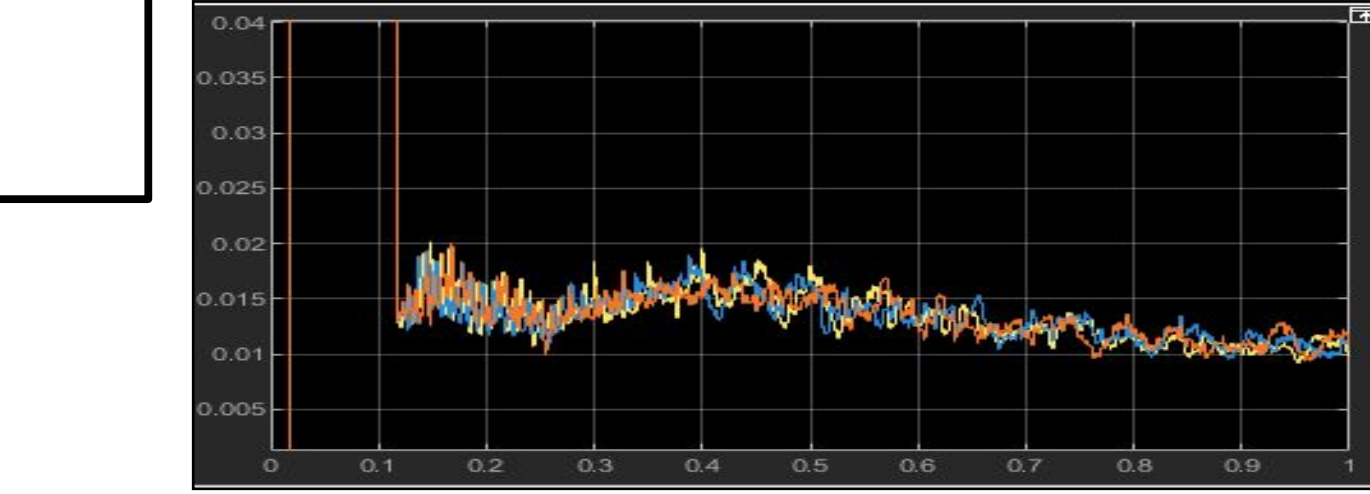
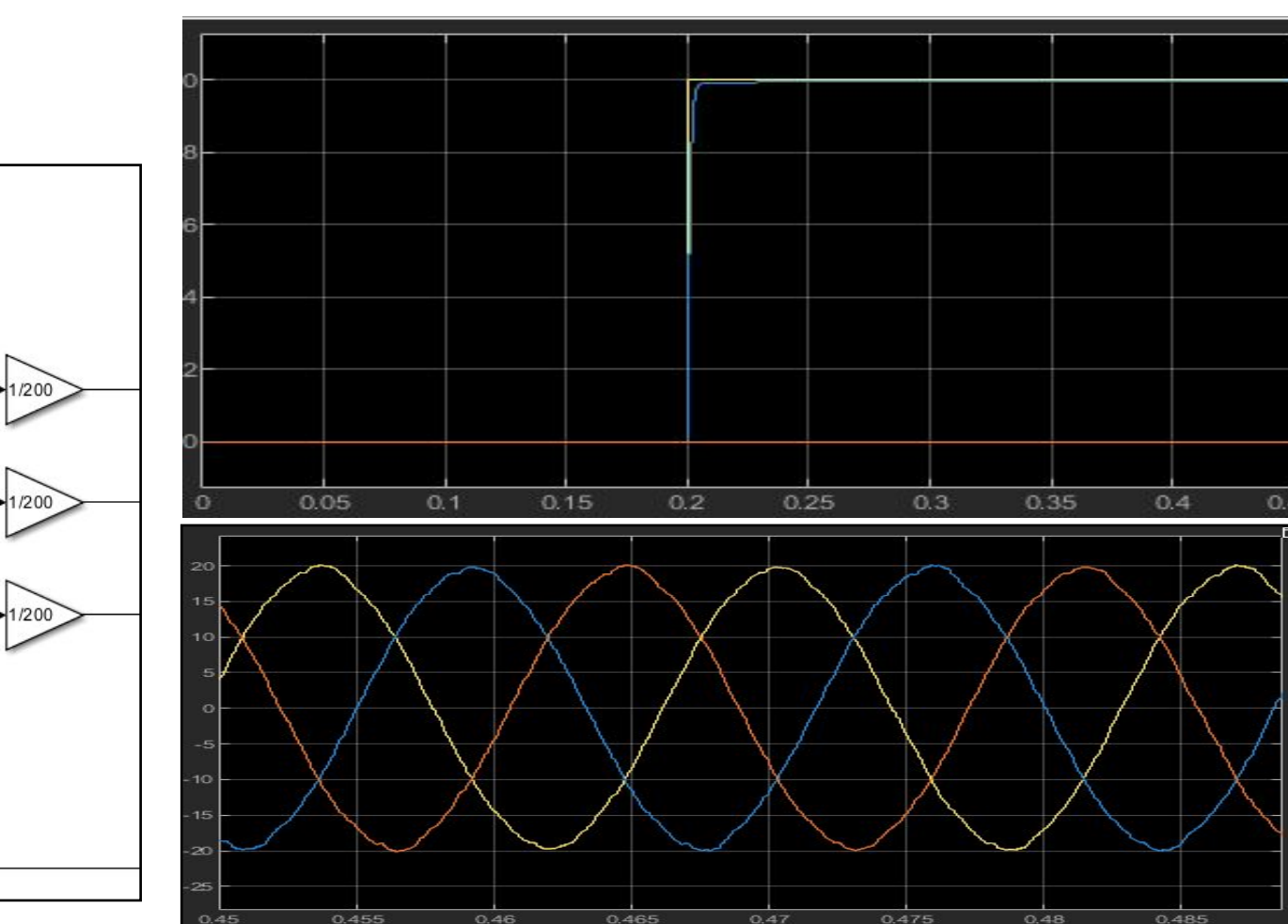
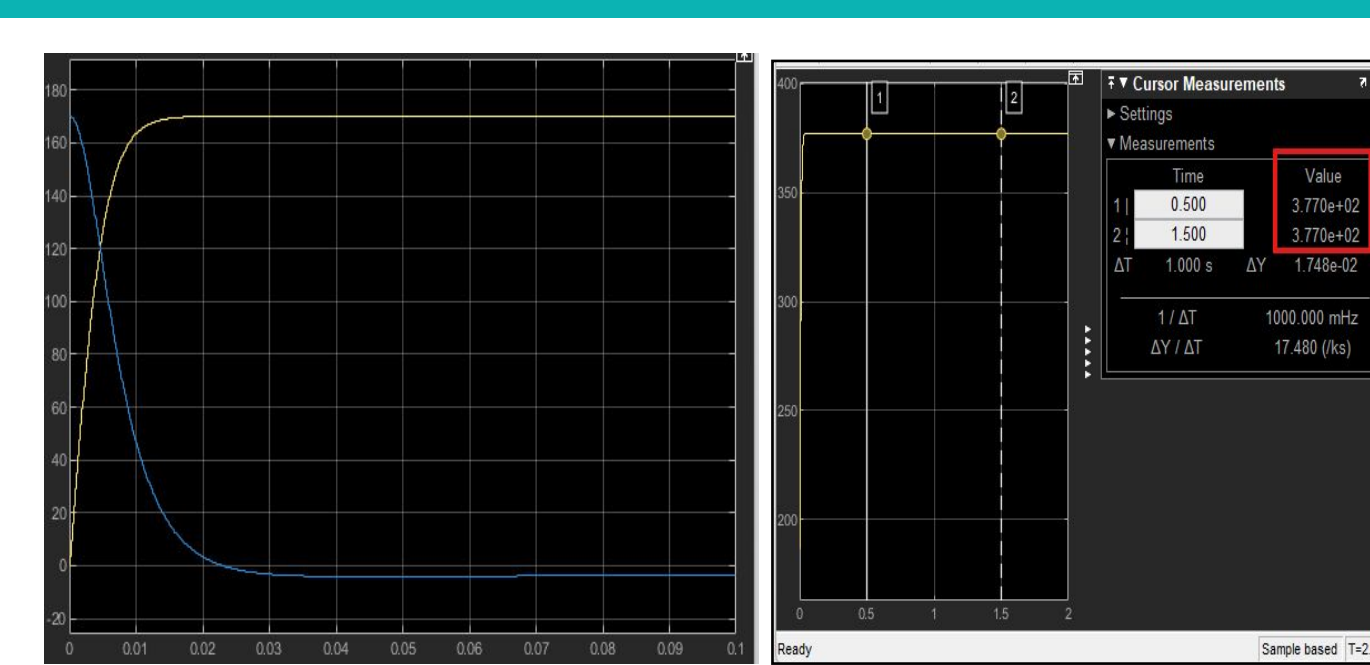
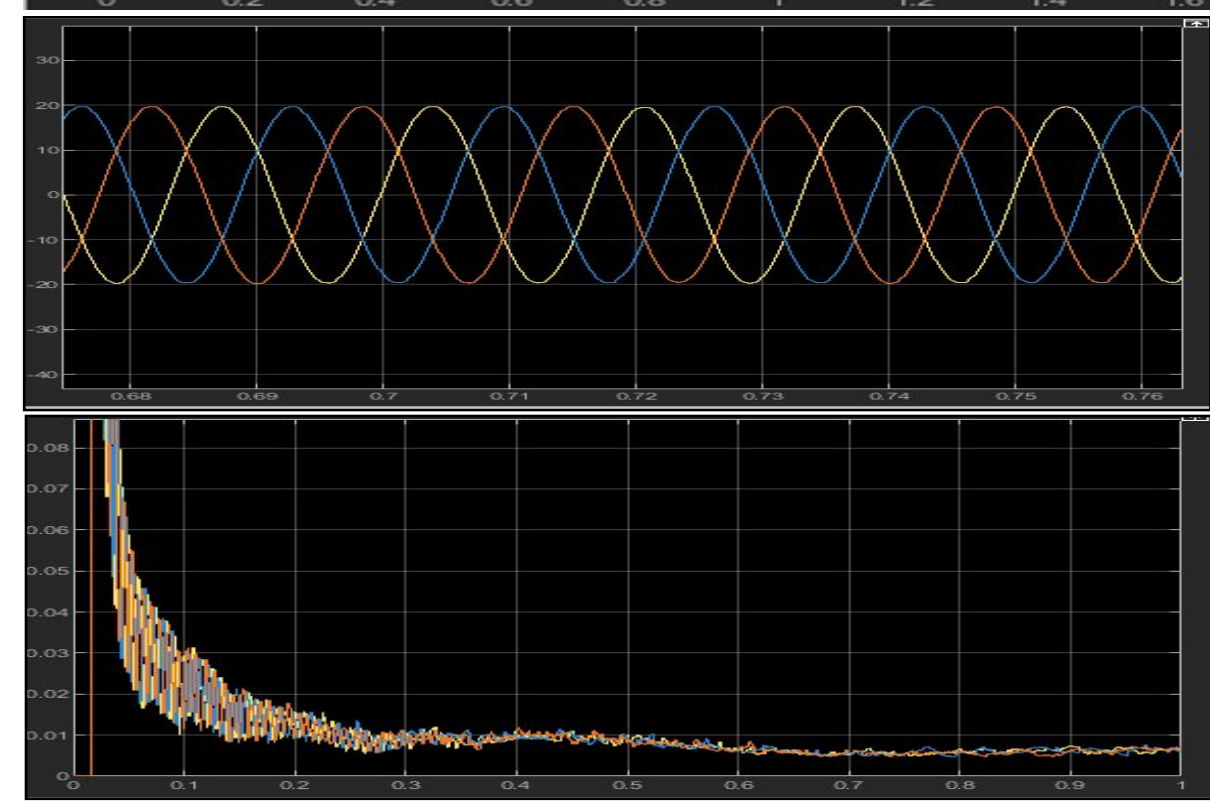
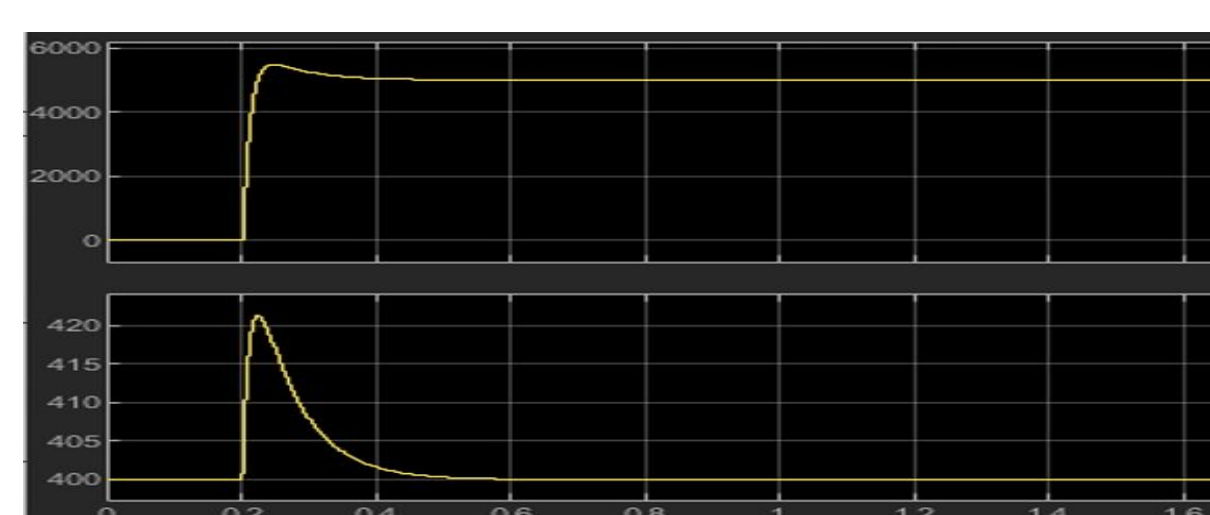
System Components



Phase 1: Vd(yellow), Vq(blue).
Omega_est(377 [rad/s]).



Phase 2: id_meas(blue), id_ref(yellow).
Iabc @ 0. THD @ 2%.



Phase 3: Pout @ 5kw. Vdc regulates @400v.
Iabc @ 0. THD @ 2-3%



IEEE Key Performance Specifications Standards

- IEEE 519: THD must be below 5%.
- IEEE 2800-2022: PLL must be capable of following changes in the applicable voltage of up to 25 degrees during phase angle changes.
- IEEE 2800-2022: Steady state voltage must be regulated to within $\pm 1\%$ of voltage setpoint.
- IEEE 2800-2022: Must have the capability to inject or absorb reactive power equivalent to 0.95 power

Testing & Verification

- Achieved stable grid synchronization at 60 Hz (377 rad/s)
- d-axis voltage converges to 170 V
- q-axis voltage converges to 0 V (proper phase alignment)
- Current controllers (d-q PI)
 - Accurate tracking of reference current
 - Proper decoupling ($i_q \approx 0$)
- Total Harmonic Distortion (THD):
 - $\approx 2\%$ per phase
 - meets IEEE 519 (<5%)
- Full system performance
 - power output converges to 5000 W
 - DC bus voltage regulated at 400 V
- Stable operation observed after transient response
- No sustained oscillations or instability

System Integration

- Testing was conducted in three primary progressive phases:
- Phase One: PLL Functional Test - Verifies grid synchronization and confirms that the output maintains stable frequency tracking
 - Vd reaching a steady state of the input voltage (170 V)
 - Vq reaching a steady state of 0V
 - omega_est locking onto the grid angle (377 rad/s)
 - Phase Two: PLL + Current Controller Integration Test - Validates current tracking performance and ensures proper decoupling of the d-q axes
 - I_abc output reaching a steady state (centered around zero)
 - THD for each phase of approximately 2%
 - Phase Three: Full System Integration Test (PLL + Current Controllers + DC Bus Voltage) - Integrates the voltage controller and verifies power delivery and overall system stability
 - I_abc output with initial transient response reaching a steady state (centered around zero)
 - THD approaches a steady state between 2% and 3%

Conclusion

The InverTech successfully validated a three-phase grid-tied inverter in Simulink and Simscape Electrical, achieving stable grid synchronization and maintaining THD below 5% in compliance with IEEE standards. Providing a strong foundation for control validation and future hardware deployment.