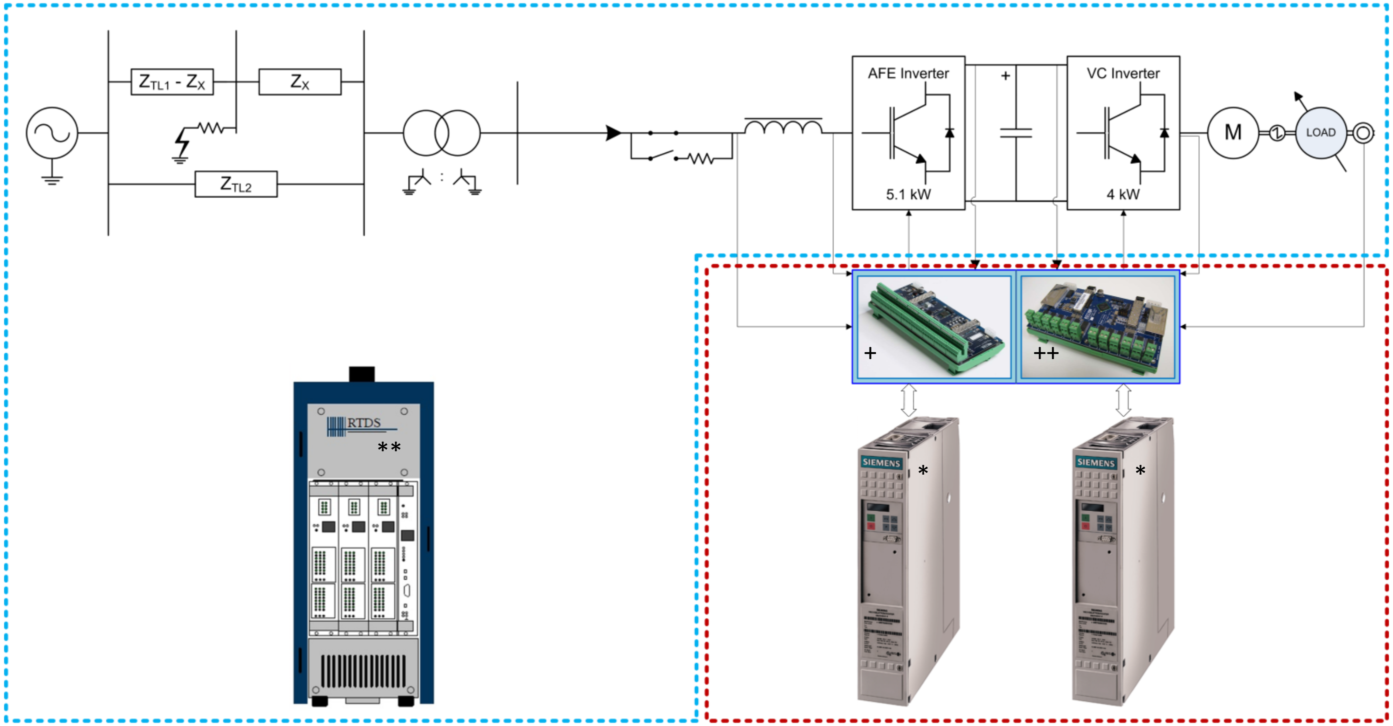
HARDWARE-IN-LOOP TEST TO ASSESS THE PERFORMANCE OF ADJUSTABLE SPEED DRIVES IN RESPONSE TO POWER QUALITY EVENTS



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1. Project Introduction

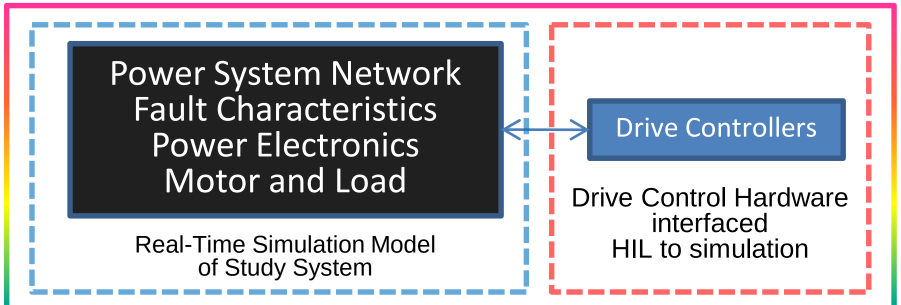
- The effect of upstream faults on the performance of drive systems is a subject of great interest within the research and industrial environments.

- Modern industrial drive systems are complex units that are commissioned based on the desired motion control task at hand.

- In order to accurately analyze the performance of these drive systems, the actual control hardware should be used.

- The focus of this project is the development of a study system to examine a possible approach for analyzing the response of drive systems during voltage dip conditions.

- This approach is based on interfacing a real-time simulation model of the plant with practical drive controllers connected hardware-in-loop (HIL).

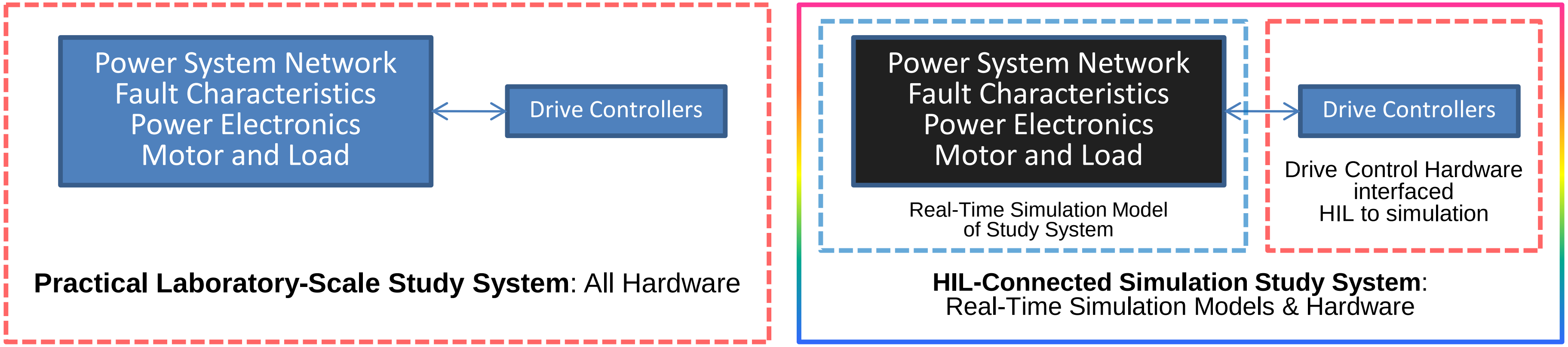


HIL-Connected Simulation Study System:
Real-Time Simulation Models & Hardware

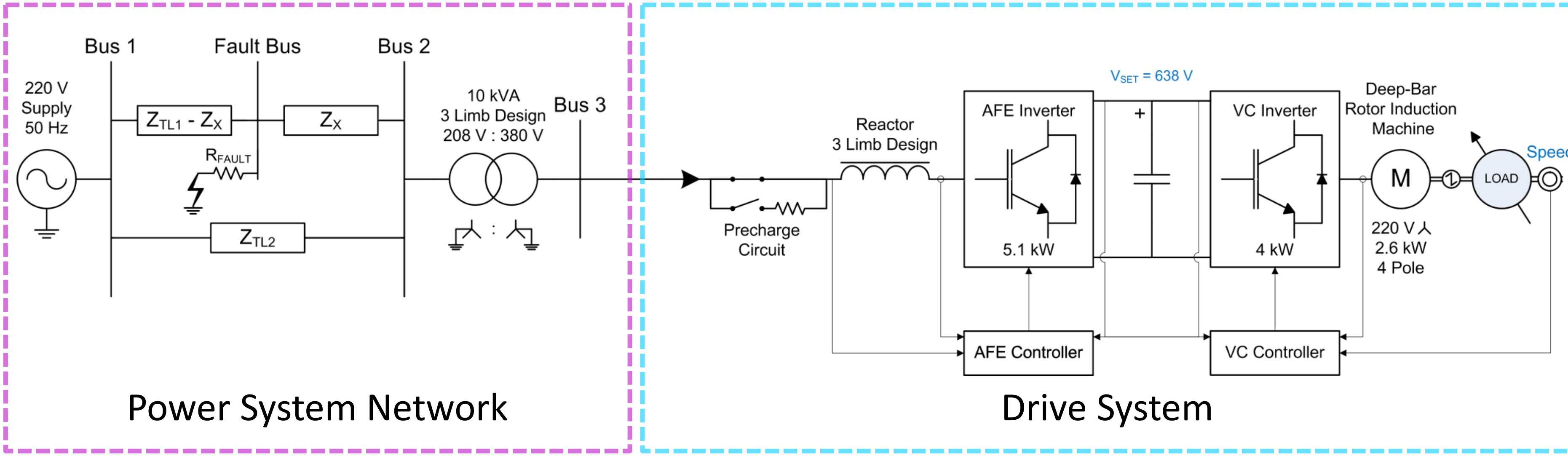
2. Evaluation Procedure

To assess the validity and accuracy of the suggested approach, the following procedure was applied:

- A complete practical laboratory-scale study system was designed and commissioned to serve as a benchmark.
- A selected set of fault tests was applied to this practical system and its performance was measured.
- Real-time simulation models of the components of this practical system were developed, parameterized and tested to verify their suitability and accuracy.
- These real-time models were then interfaced to the practical drive controllers to form the HIL-connected simulation study system.
- The same selected set of fault tests was then applied to the HIL-connected simulation study system and its performance was recorded.
- The measured performance of the practical study system was then compared to the performance of the HIL simulation study system to assess the validity of the HIL testing approach.



3. Study System

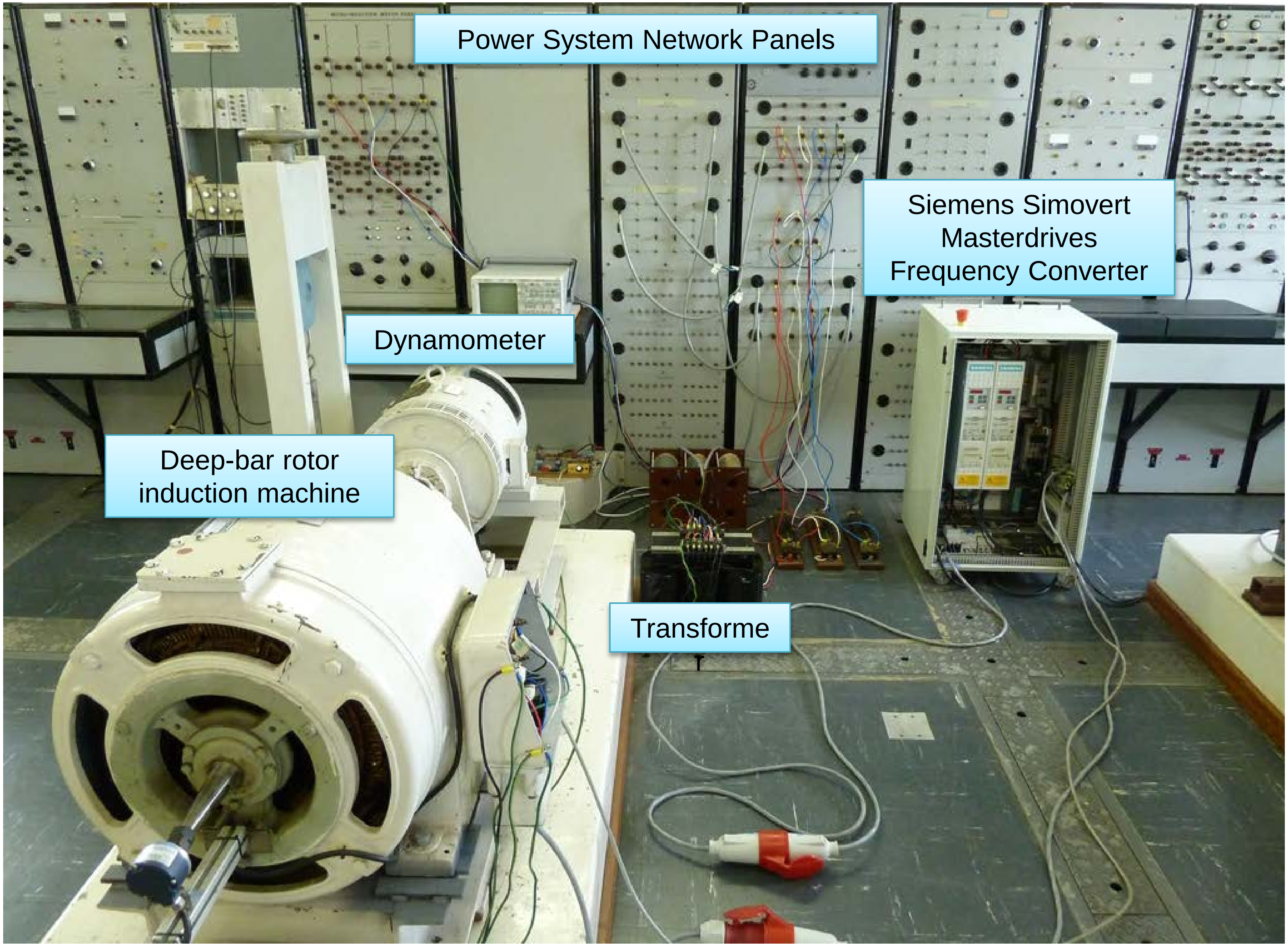


- The Power System Network contains:
  - 3-phase, 220 V source at Bus1 supplying two transmission lines TL1 and TL2 which terminate at Bus 2,
  - 10 kVA, 3 limb transformer fed at Bus 2 steps up the voltage to 380 V at Bus 3, and
  - Fault Bus located within TL1, where the system disturbances are produced.

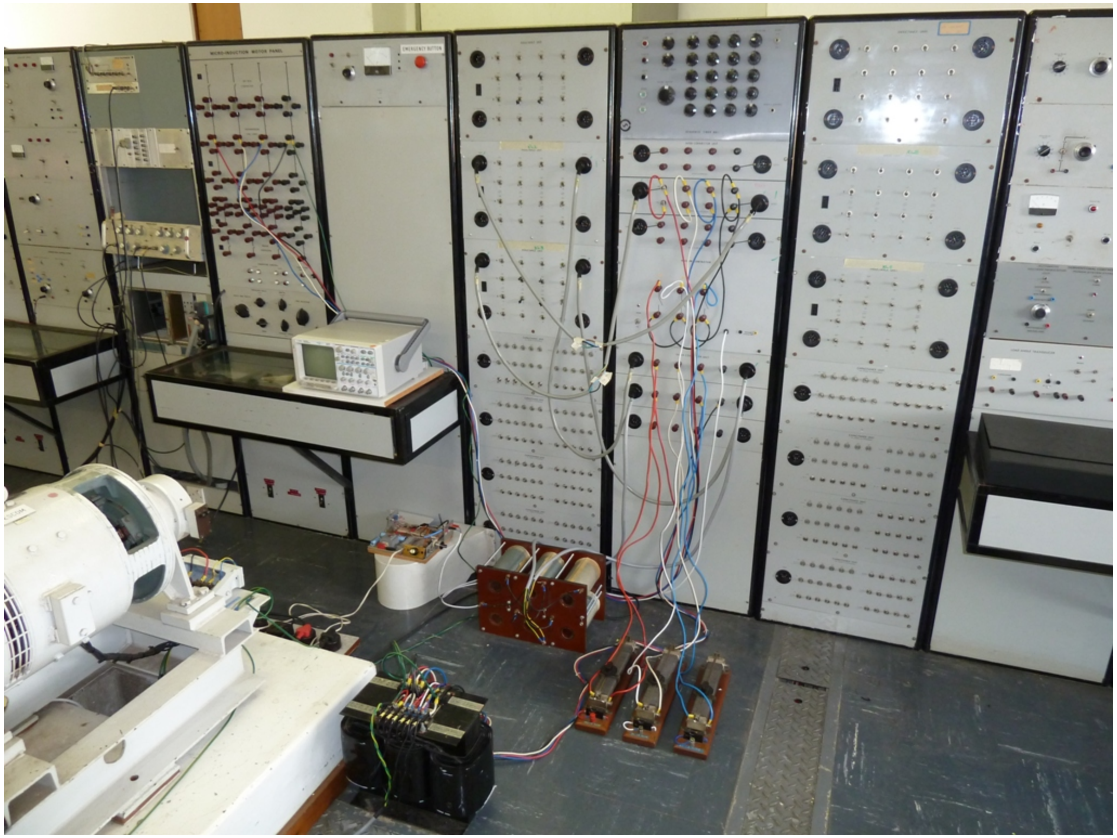
- The Drive System consists of:
  - Siemens Simovert Masterdrives Frequency Converter, and
  - deep-bar rotor induction machine coupled to a dynamometer.

- The Frequency Converter is made up of:
  - an IGBT based Active Front End (AFE) rectifier/regenerative feedback unit, and
  - a Vector Control (VC) Motor Inverter.

4. Practical Implementation of the Study System



4.1 Power System Network



- The transmission line impedances are represented by air and air-gapped iron cored inductor banks.
- The network topology was chosen to allow desired voltage dips at the drive bus by applying a variety of actual asymmetric short-circuit faults on the upstream network that are within the physical capabilities of the laboratory equipment.
- The fault type, duration and voltage dip severity may be altered to produce complex realistic disturbance patterns at the drive system input.

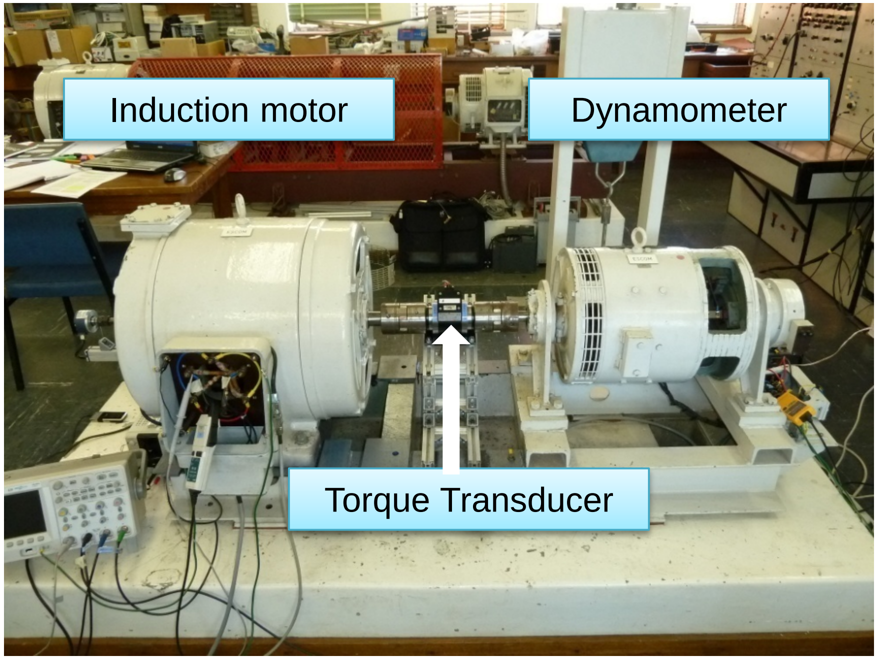
4.2.1 Induction Motor and Load

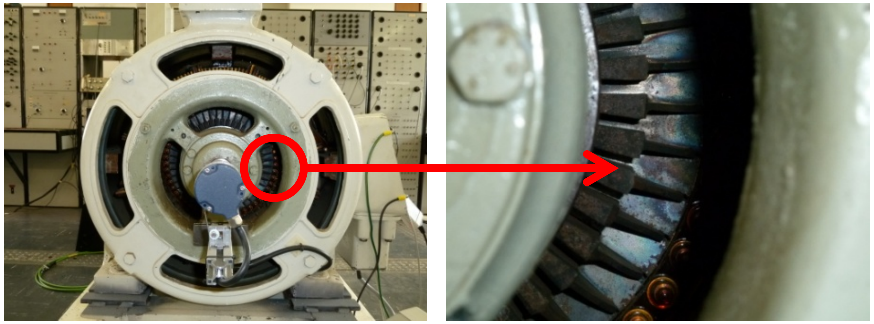
- Mawsdley micro-induction machine coupled to the dynamometer via a torque transducer.

- Micro-induction machines are designed to have per-unit parameters that are representative of large megawatt sized machines

    - hence the dynamic performance of this type of machine during testing is comparable to that of a megawatt-sized machine.

- The rotor has a deep bar design also representative of large machines.





Section of deep bar rotor

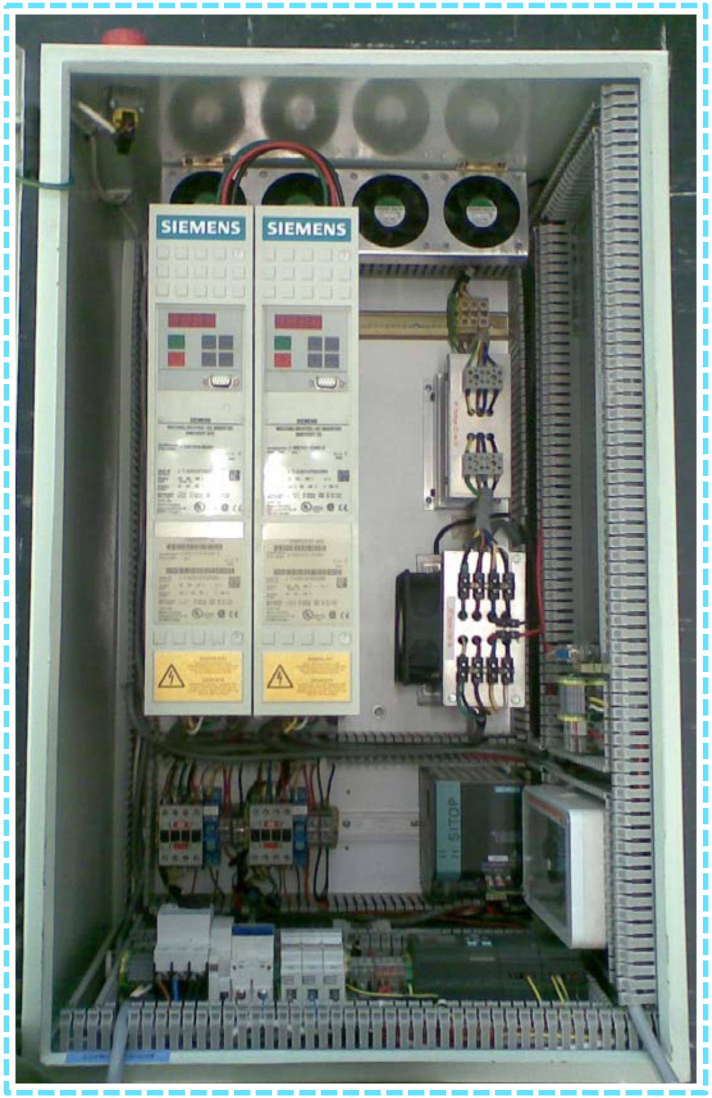
4.2.2 Drive System: Frequency Converter

Active Front End Unit

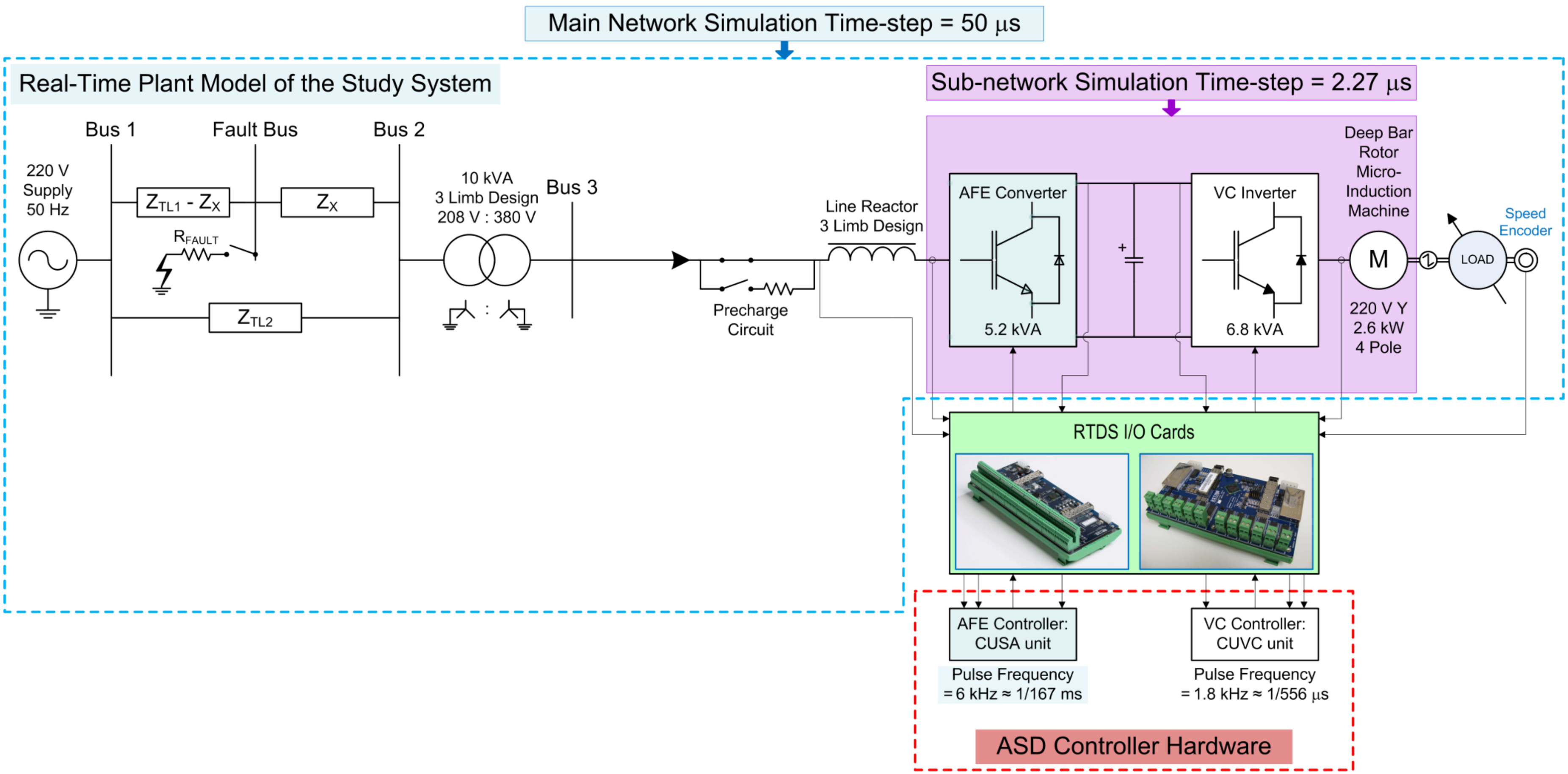
- ➢ Maintain a constant DC bus supply with:
  - Closed-loop DC-link voltage control
  - Closed-loop current control using the vector control algorithm

Vector Control Motor Drive Unit

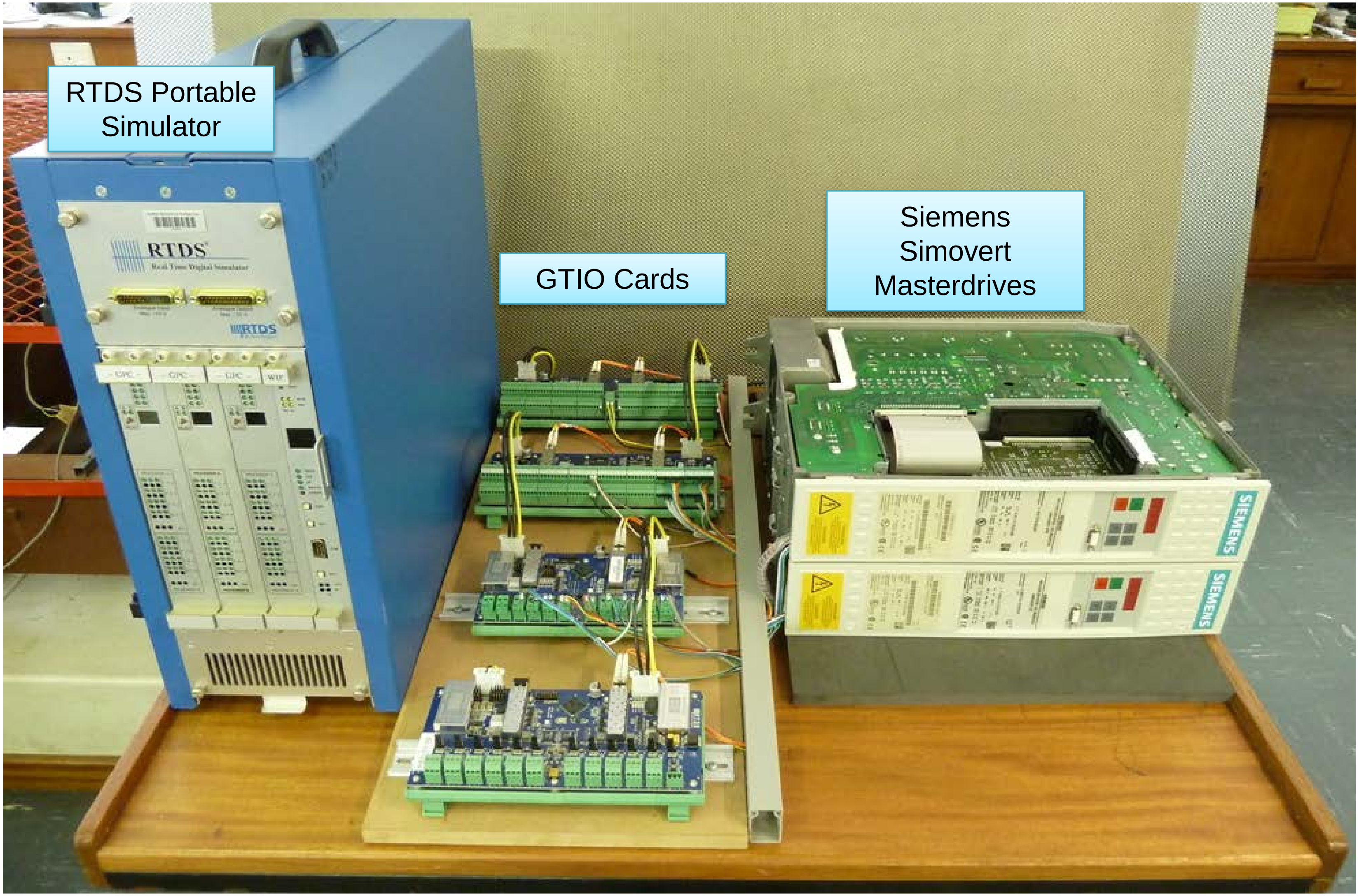
- ➢ Maintain a constant motor speed with:
  - Closed-loop speed control
  - Closed-loop torque control using the vector control algorithm…



5. HIL Simulated Study System

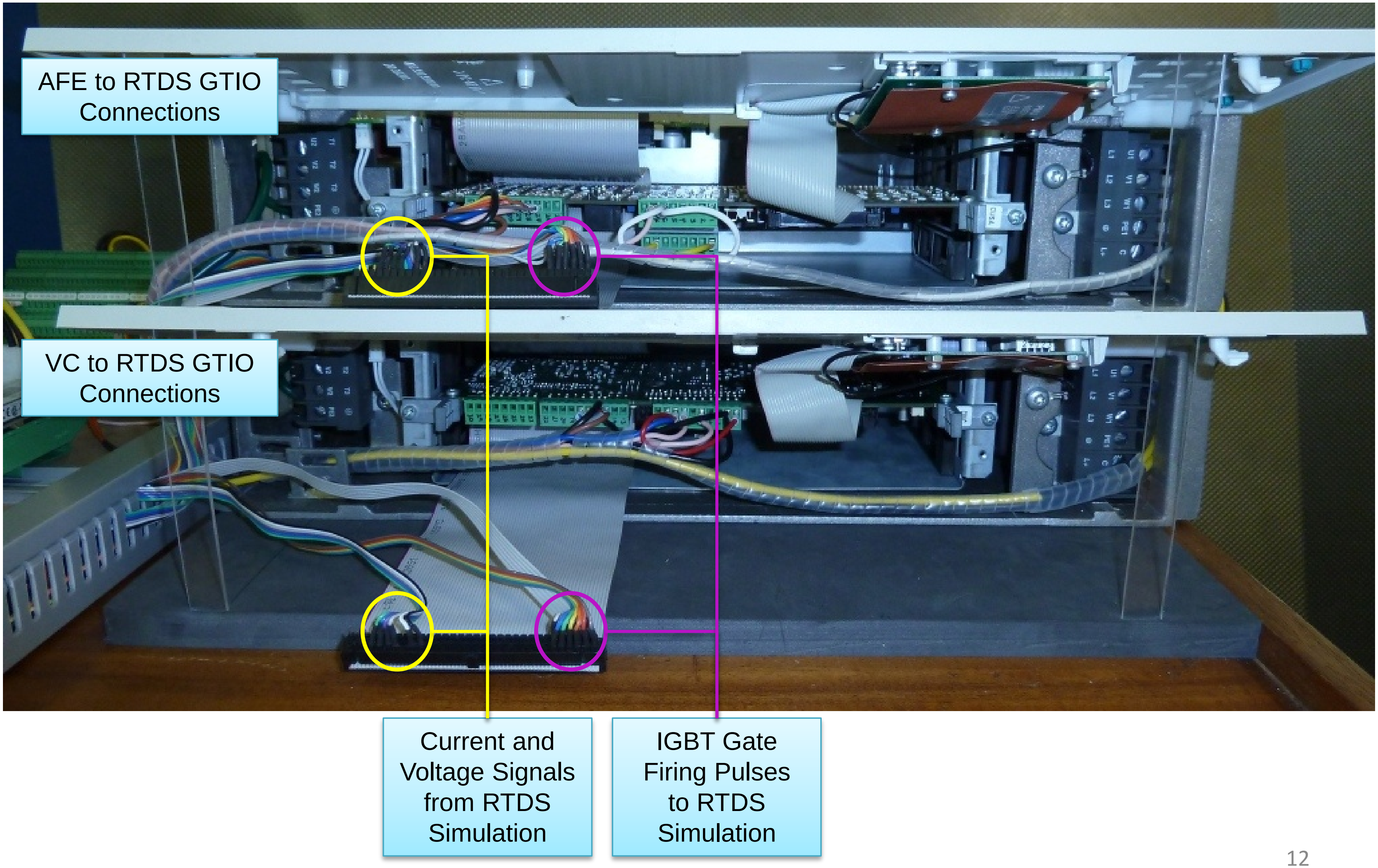


6. Implemented HIL Simulated Study System

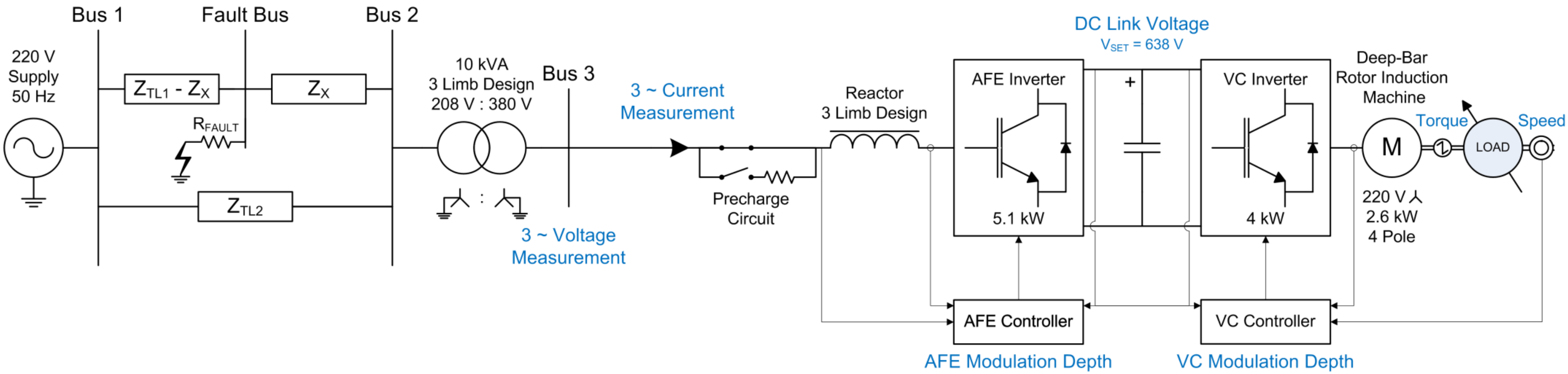


6.1 Frequency Converter Connections

6.2 Frequency Converter HIL Connections

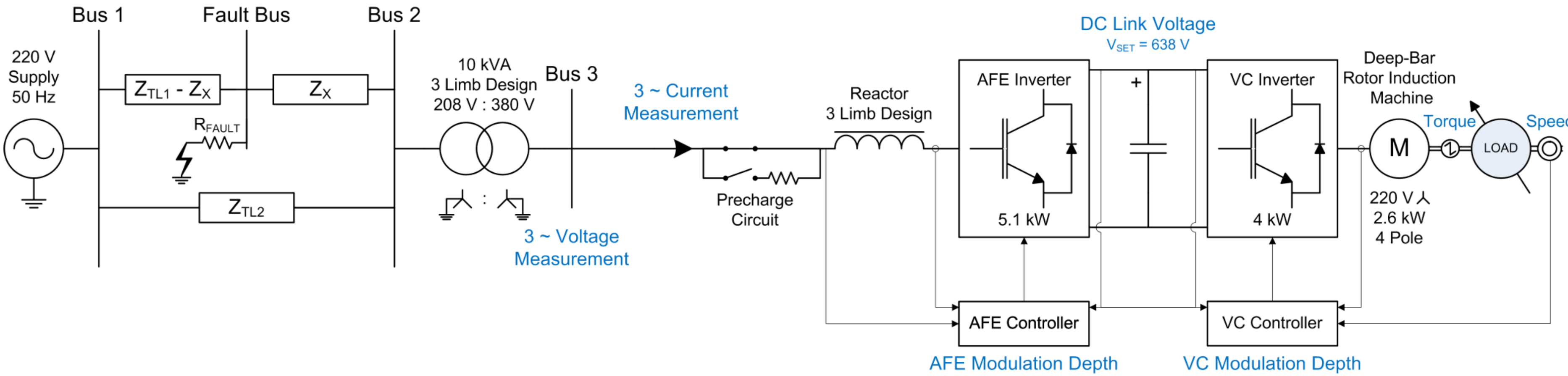


7. System Setup



- For both All-hardware and HIL simulated systems, the following initial setup was applied:
  - Source energized, and the Drive System running under speed control driving an ≈ 8 Nm load at 157 rad/s.
  - **Fault Testing:** While the system is running, faults were then applied with possible variations in
    - Type: A phase to ground (A-g), A and B phase to ground (AB-g), all phases to ground (ABC-g).
    - Duration: ≈ 100 ms to 200 ms.
    - Voltage Dip Depth: 35 %, 50 %, or 70 % on the faulted phase.
  - **Measured Quantities:**
    - Drive supply voltages and currents for all phases.
    - DC-link voltage and the modulation depth of the firing pulses sent to the AFE and VC inverters
    - Load torque and rotor speed

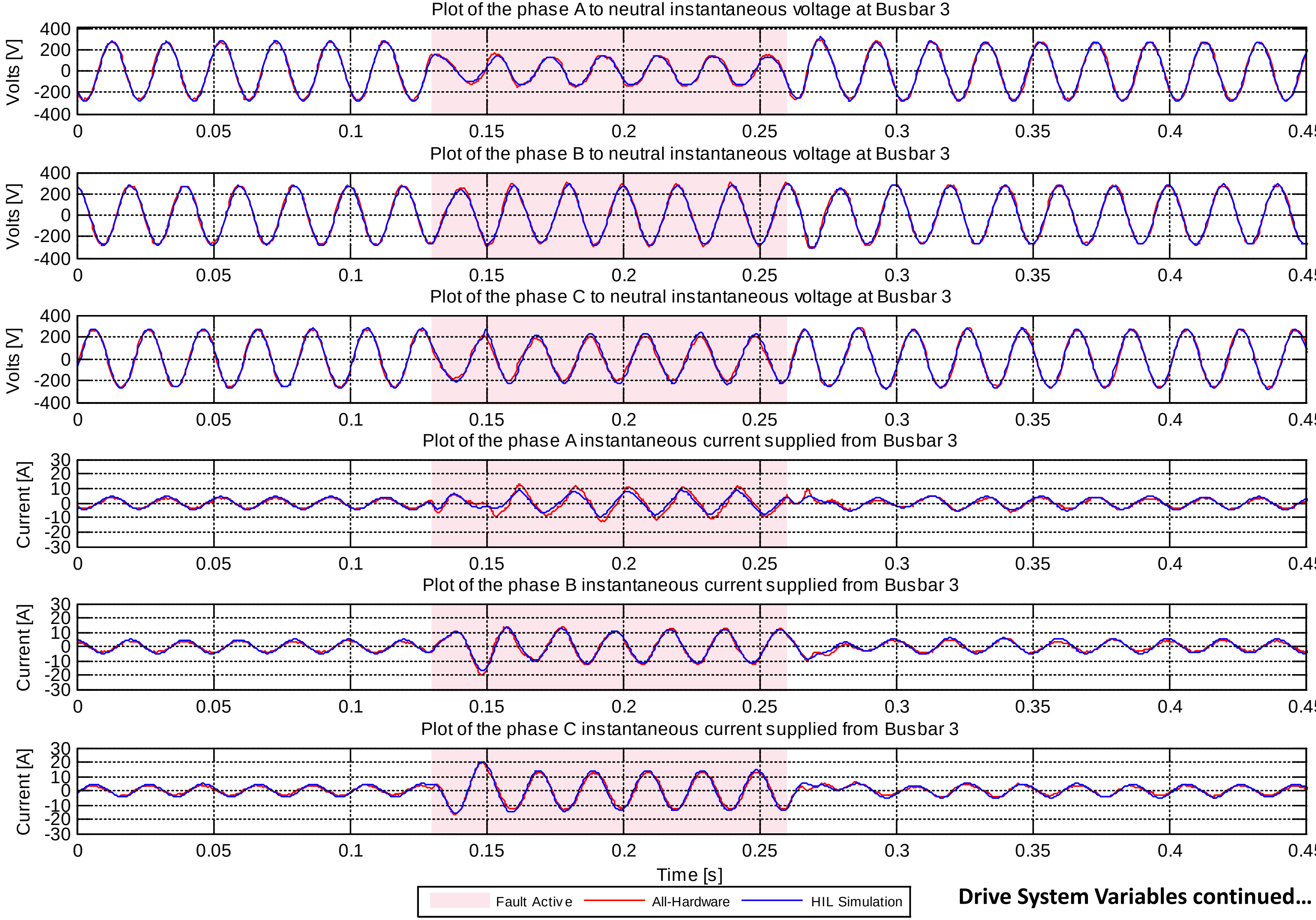
7. System Setup



➢ The performance of both practical laboratory-scale and HIL simulated systems during the application of the following faults is presented:

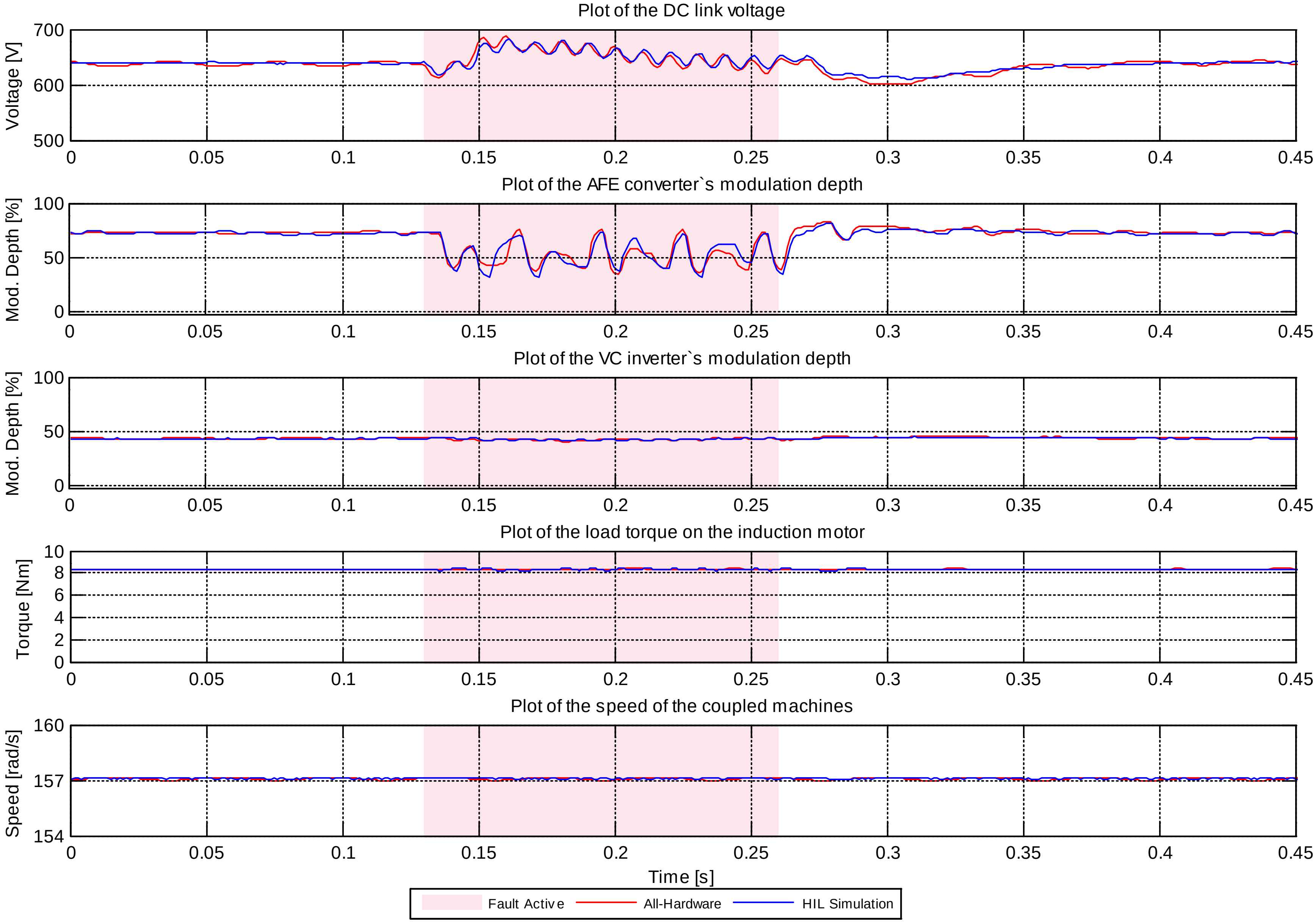
	Fault Type [Phase/s - ground]	Duration [ms]	Voltage Dip Depth [%]	Voltage During Fault [%]
i	A – ground	100	50	50
ii	ABC – ground	100	50	50
iii	ABC – ground	100	70	30

i. Phase A-g Fault with 50 % Voltage Dip : Bus 3 Variables

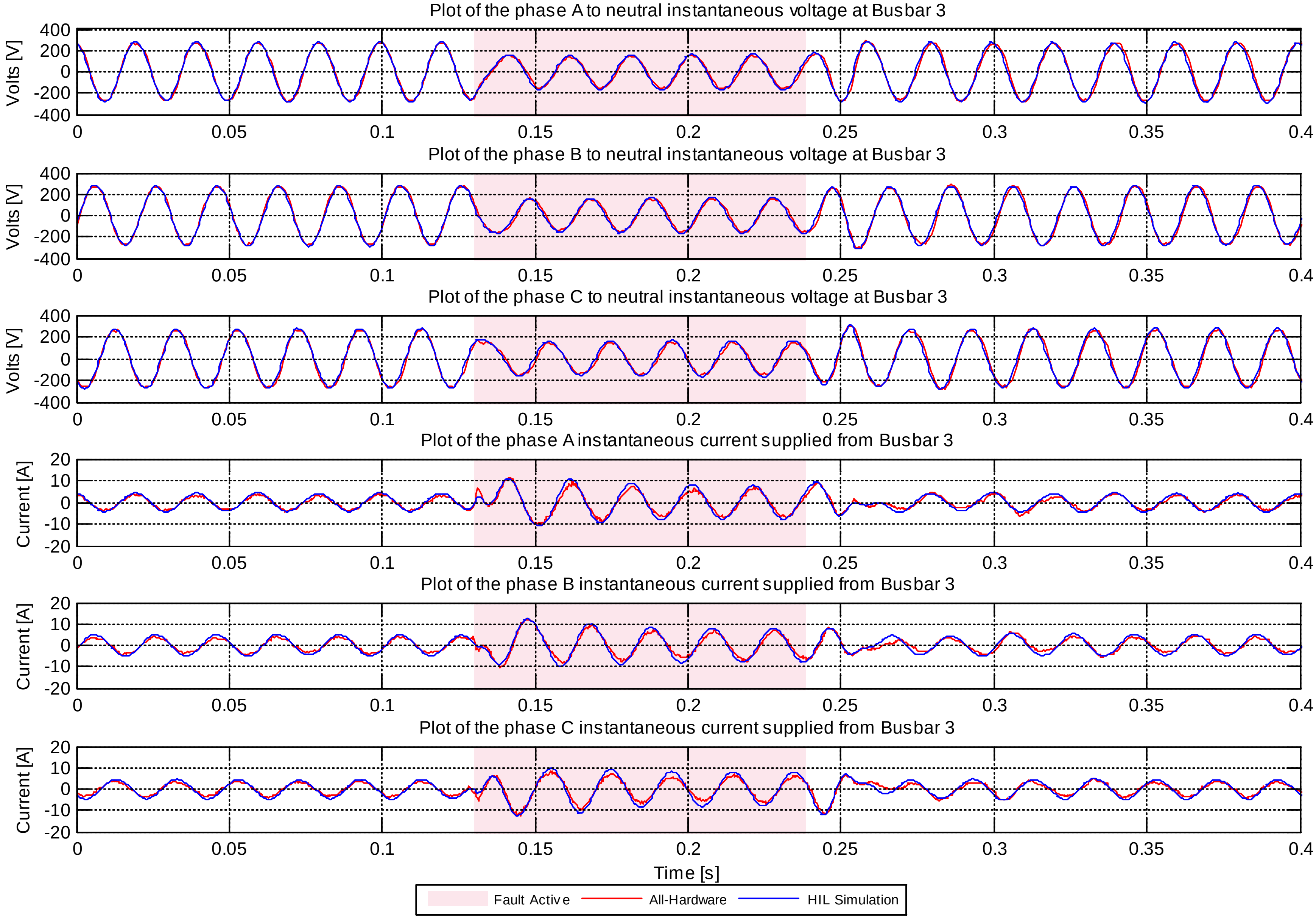


Drive System Variables continued…

i. Phase A-g Fault with 50 % Voltage Dip : Drive System Variables

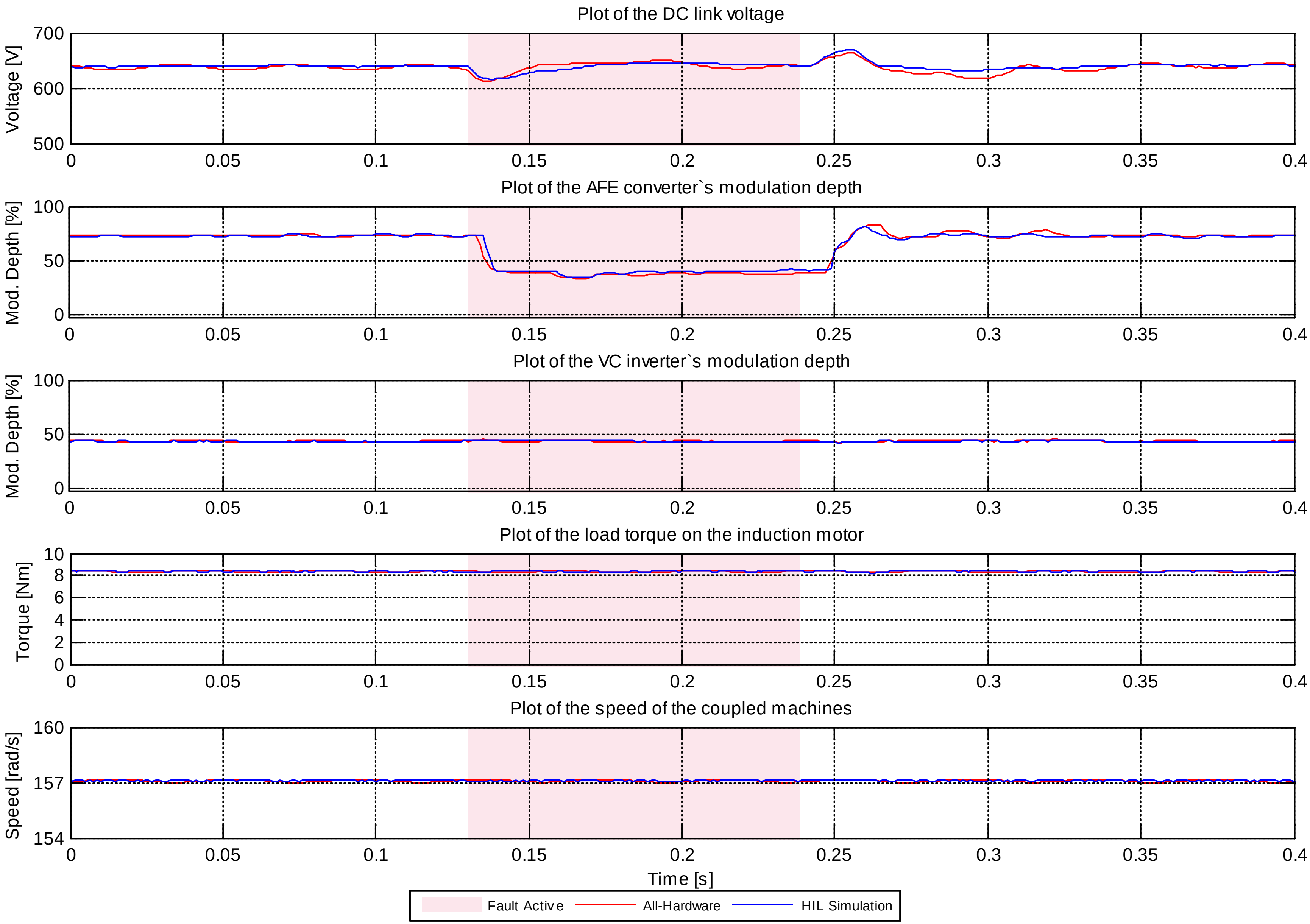


ii. Phase ABC-g Fault with 50 % Voltage Dip : Bus 3 Variables

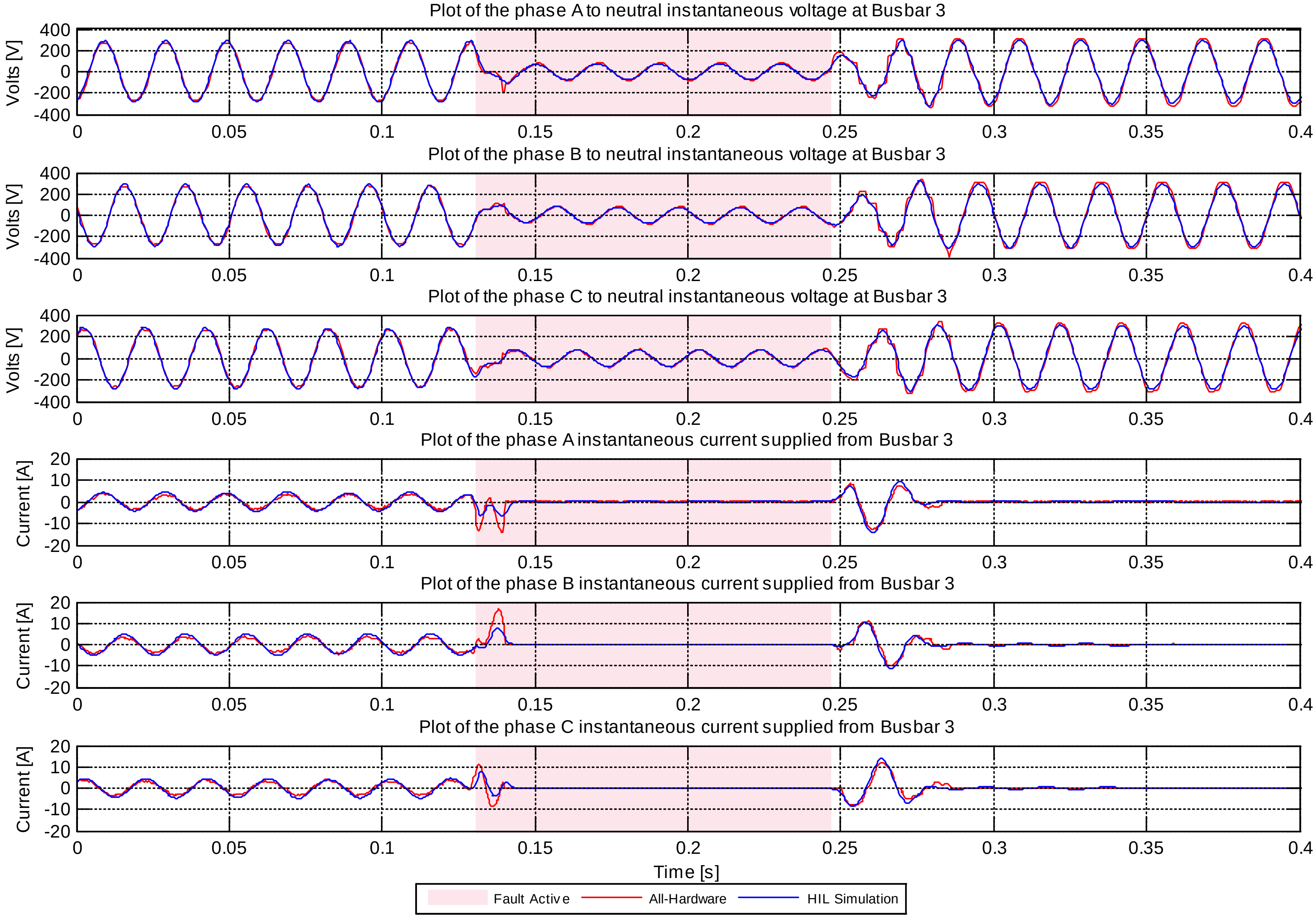


Drive System Variables continued…

ii. Phase ABC-g Fault with 50 % Voltage Dip : Drive System Variables

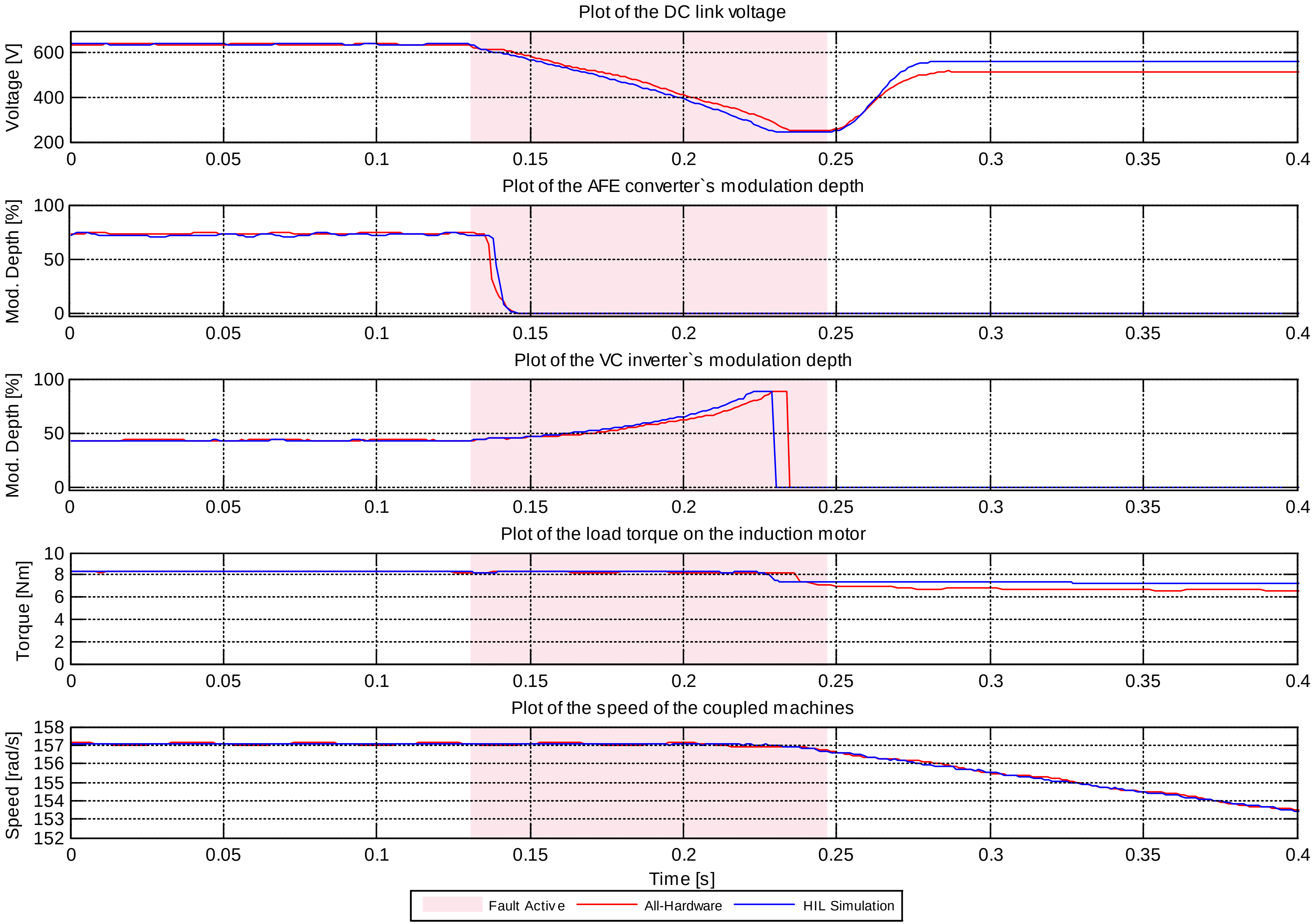


iii. Phase ABC-g Fault with 70 % Voltage Dip : Bus 3 Variables



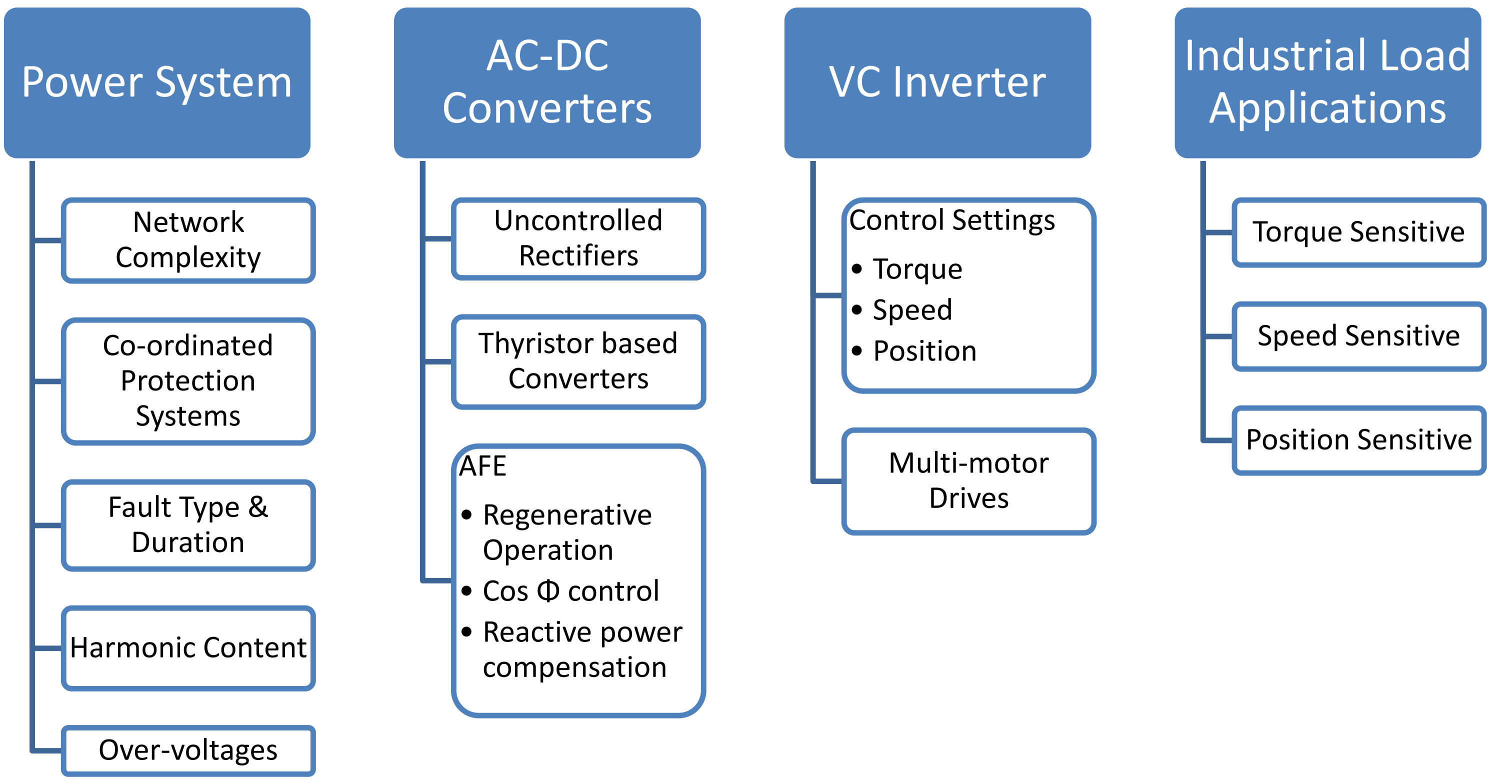
Drive System Variables continued…

iii. Phase ABC-g Fault with 70 % Voltage Dip : Drive System Variables



8. Evaluation of HIL Testing Method

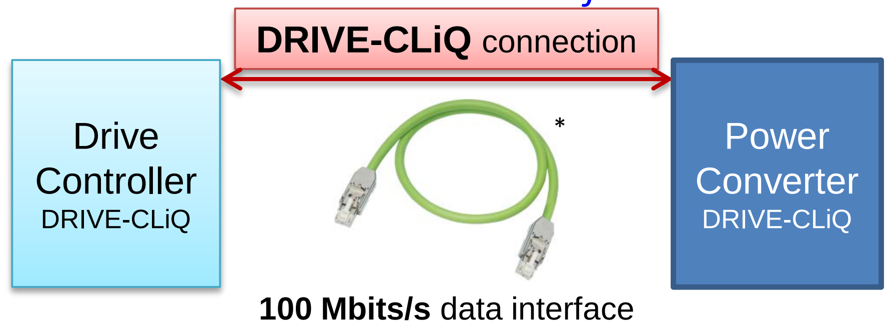
- Based on the very good agreement between laboratory-scale and HIL-connected simulation study systems during the tests, the presented approach has proved to be a sufficiently accurate technique to predict the performance of a drive system.
- Concept of HIL testing of drive controllers is now proven on a deliberately small-scale system where cross-checking against laboratory measurements was possible.
- Scalable nature of RTDS simulation of the test plant means scope now opens up for HIL testing of more complex drive systems and supply networks than would be possible in a traditional laboratory environment.



9. Recent Development in Drive Technology

Conventional Controller Interface

New Controller Interface



- For a conventional drive, there is a need to disassemble the drive to physically trace and intercept the signals required for HIL testing → Drive warranty **void!**
- DRIVE-CLiQ is a similar concept to the IEC 61850 communication standard used to transfer data between utility protection devices.
- An ASD controller with DRIVE-CLiQ can be connected directly to an RTDS simulator via an Ethernet cable, and the signals required for HIL testing can be exchanged over this cable.
- Therefore this new type of drive does not need to be disassembled at all → Drive warranty still **valid.**
- The DRIVE-CLiQ interface therefore makes HIL testing of industrial drive systems with an RTDS simulator much more attractive for drive manufacturers and their customers in future.

Presentation Picture References:

* Image source "© Siemens AG 2015, All rights reserved"

** *RTDS™ Manuals, Hardware Manual, Cubicle & Power, HDWR-CH1-Cubicle-rev00.pdf, page 1.6.*

++ *RTDS™ Manuals, Hardware Manual, GT Analogue Output Card (GTAO), HDWR-CH7-GTAO-rev00.pdf, Cover Page.*

\+ *RTDS™ Manuals, Hardware Manual, GT Digital Input Card (GTDI), HDWR-CH10-GTDI-rev00.pdf, Cover Page.*

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