NTNU – Trondheim
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Hardware-In-the-Loop (HIL) test lab and Applications

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NTNU- Electric power engineering

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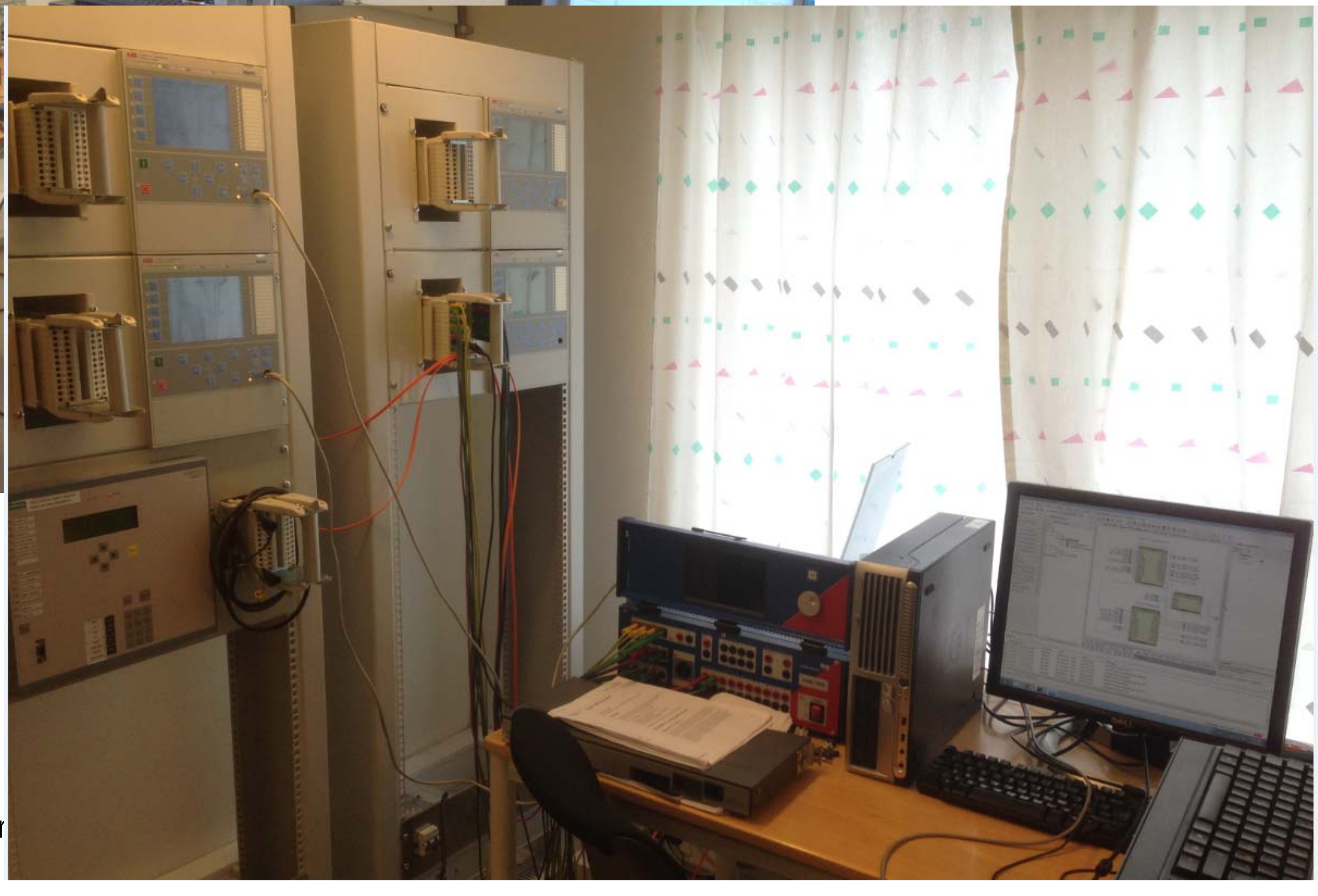
Outline

- **NTNU HIL test lab**
- **HIL applications on power system protection**

NTNU HIL test Lab - photos



NTNU HIL test lab

Motivations:

- **HIL relay testing for research and education**
- Powerful real time simulation capability for power system
  - Modern power networks
  - Complex faulty scenarios
  - Communication network
- *Interoperability to ensure integration of IEDs from different vendors*
- *Implementation and verification of wide area monitoring, protection and control*

NTNU HIL test lab

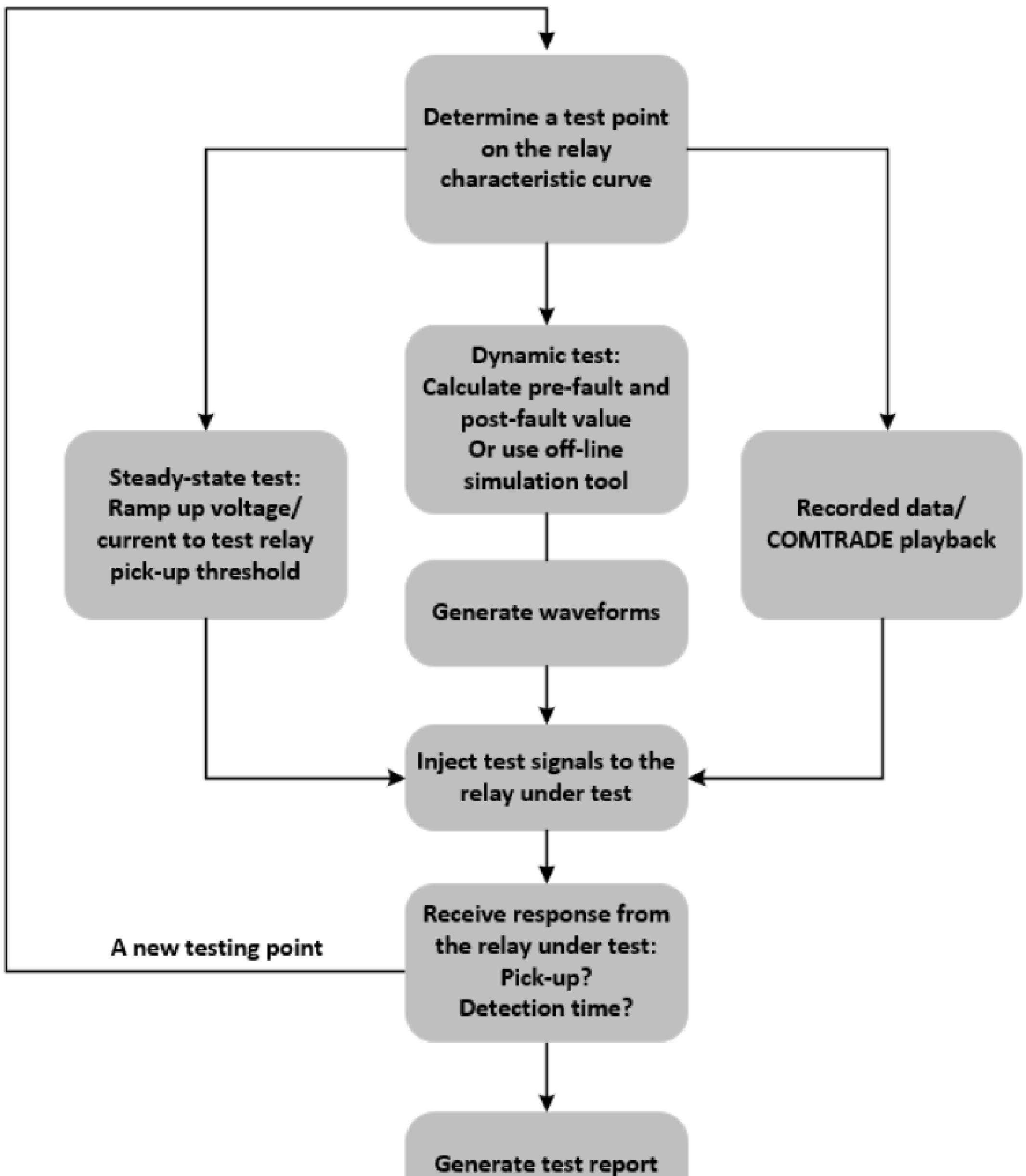
The laboratory project is divided in three phases:

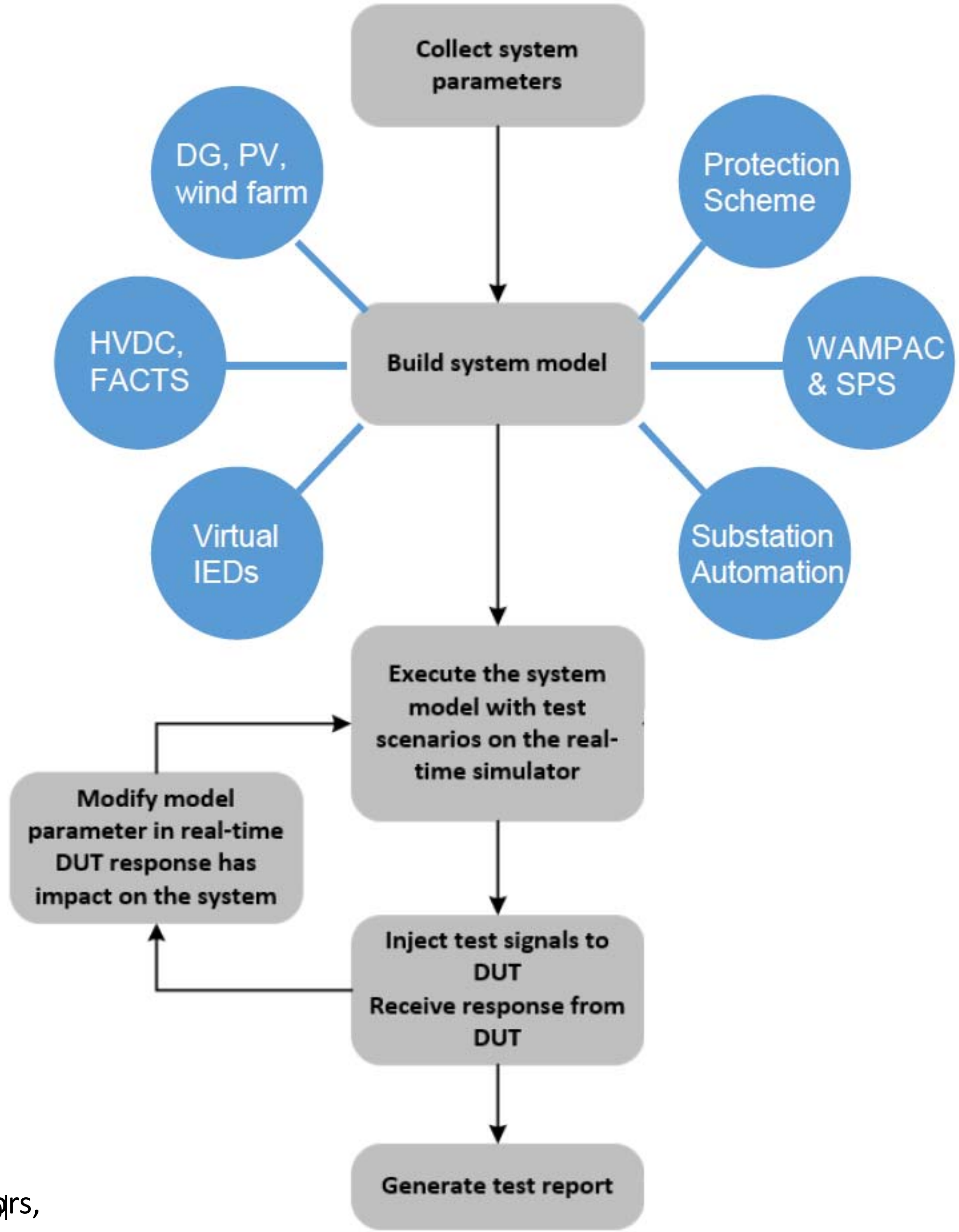
- **Phase 1**:Establish a test bench for relay setting and testing, including use of high speed data from the local process bus for transformer and bus differential, over-current, and distance protection;
- *Phase 2: Establish a SCADA interface with data concentrators and protocol converters to connect with the relay test bench;*
- *Phase 3: Establish a communication system to share remote synchrophasor data for wide-area protection and control*

Phase 1 is an important part for the normal protection courses.

And Phase 2 and Phase 3 are advanced and extended parts related to wide area protection and control against big disturbances.

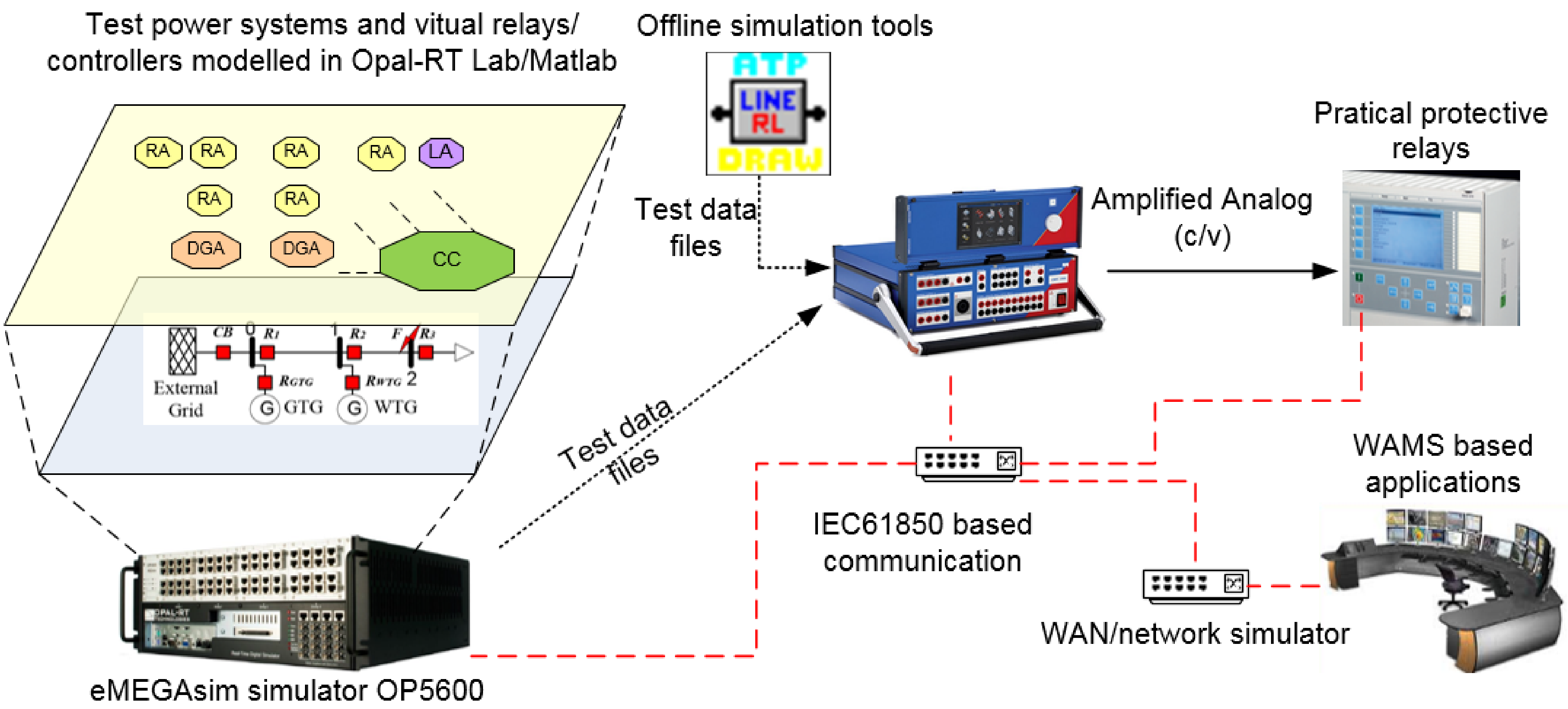
Conventional relay testing VS HIL





Ref.: Solutions overview- protection application using Real-Time Simulators, by Francois Berthelot & Shijia Li, OPAL-RT.

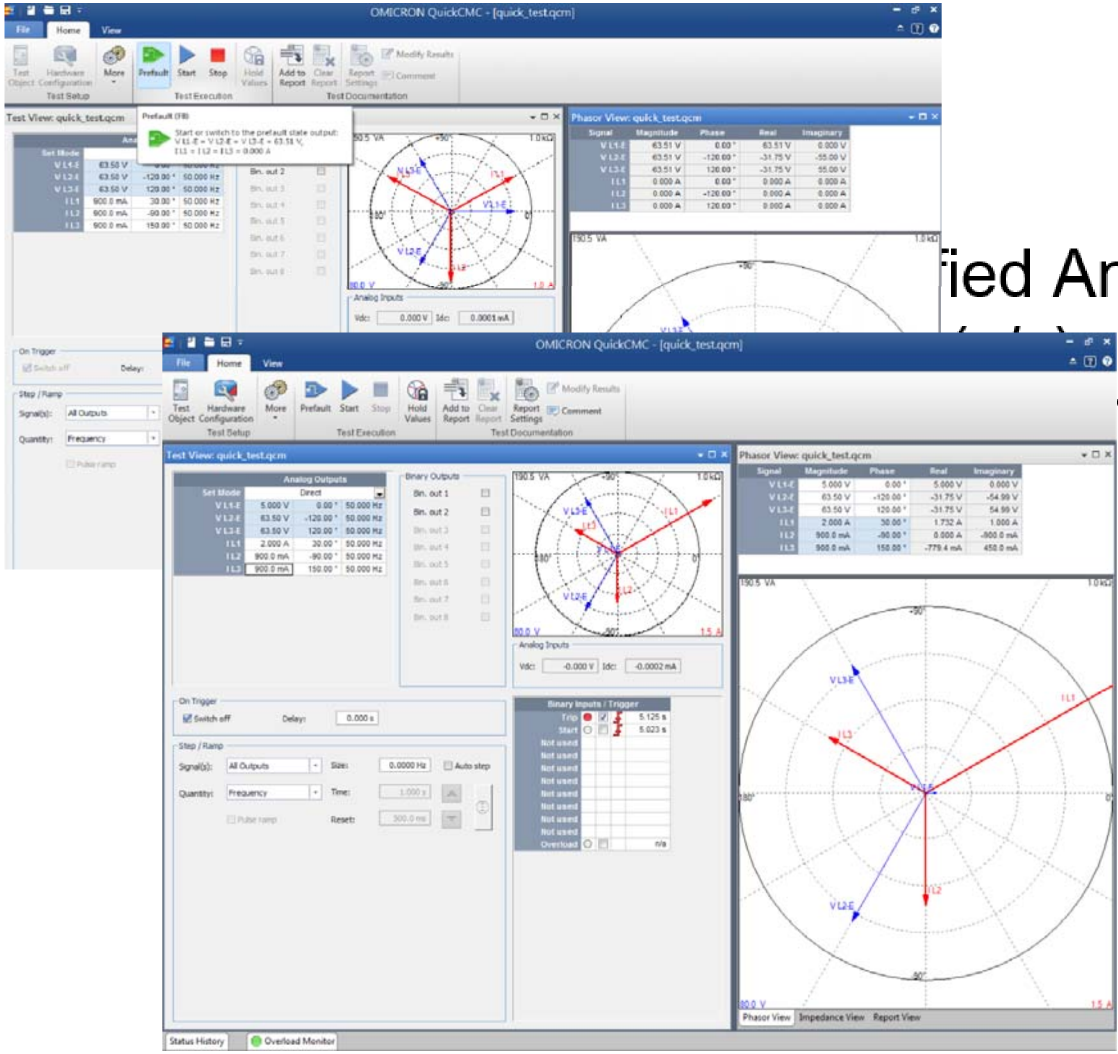
NTNU HIL test lab



Outline

- NTNU HIL test lab
- **HIL applications on power system protection**
  - **Simple test case**
  - **Adaptive distance relay and testing**

Simple test case in traditional way

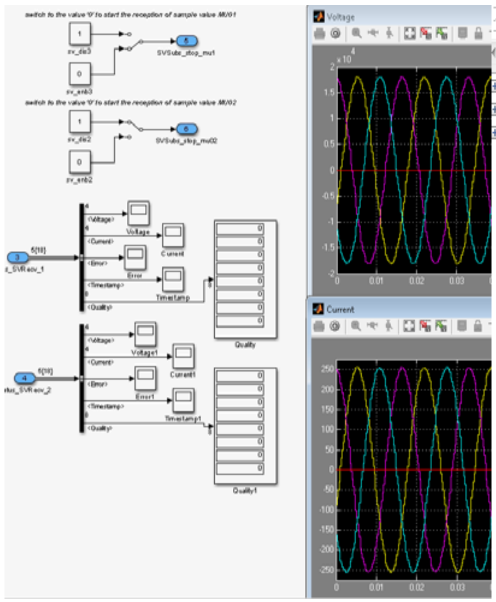


ied Analog

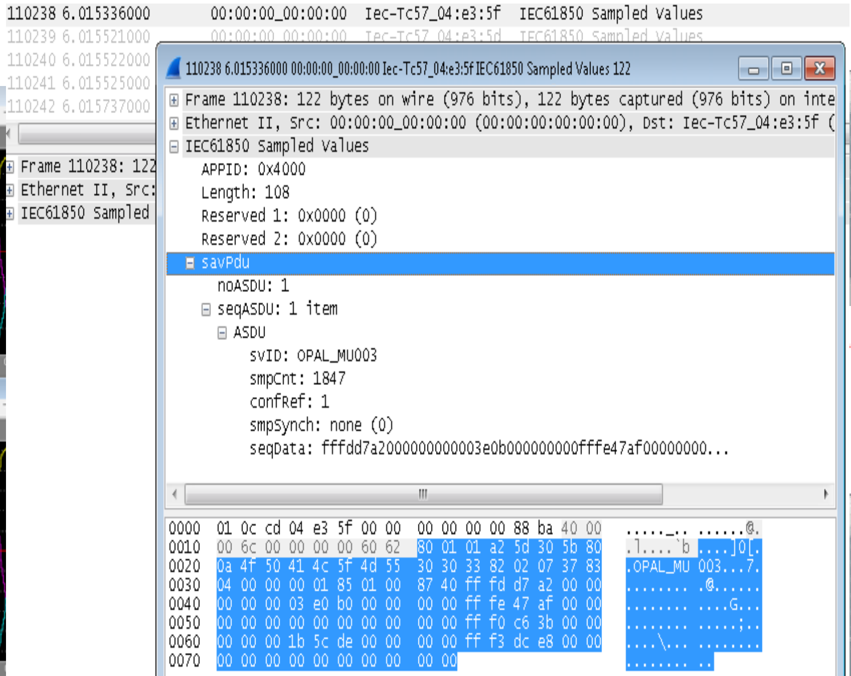
RET 670

Simple test case (Process Bus - Sample Value)

- 61850-9-2 process bus between Opal simulator and Relays
- Normal operation mode 22kV, 180.6A.

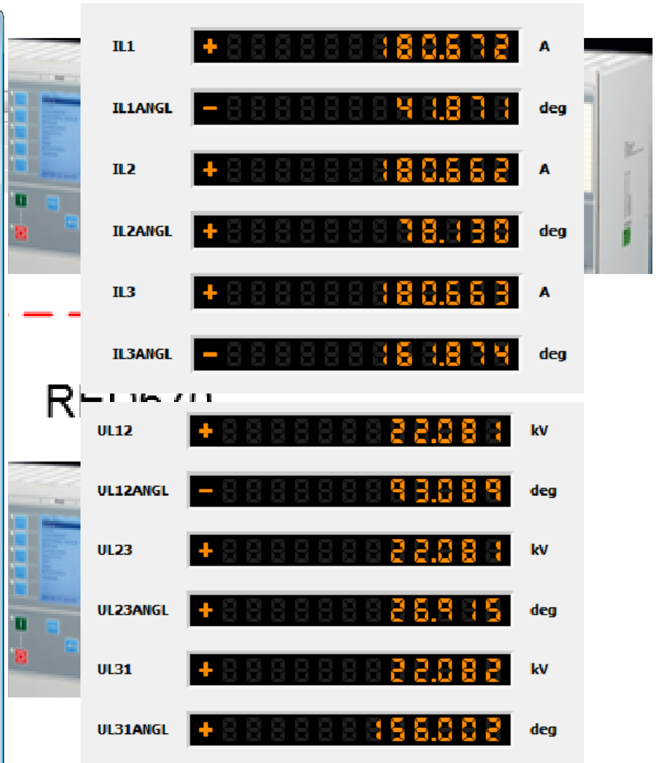


Test signals
generated by OP/



Raw data on
process bus
seen by Wireshark

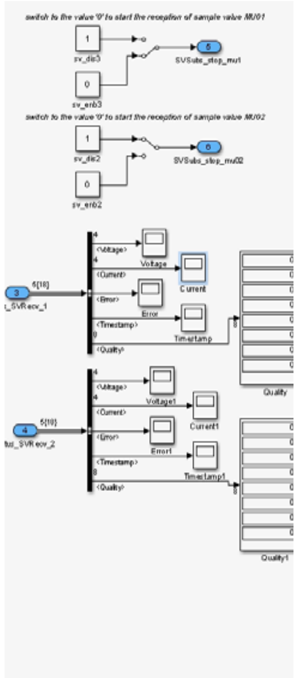
RED 670 REG670



PCM monitoring interface

Sim

- Sinç

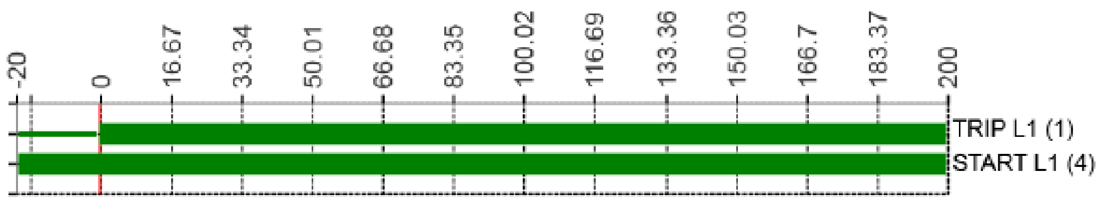


Test si
generi

ABB

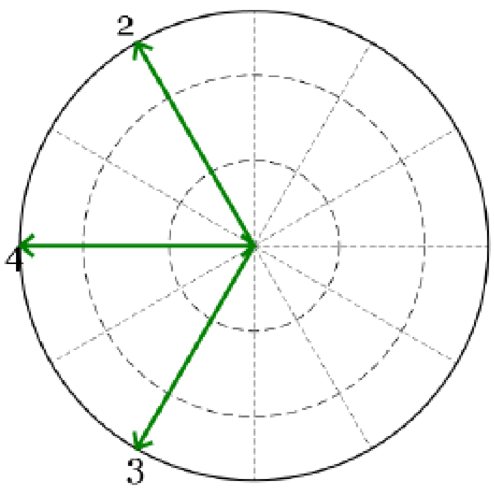
Binary Time Diagram

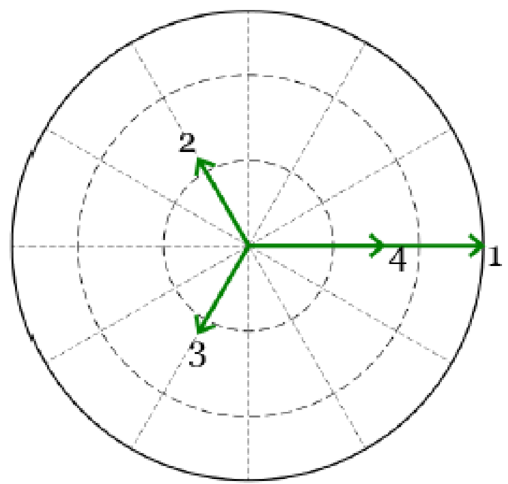
Trig Date Time: 12/26/2014 7:01:16:891 AM



Vector Diagrams

Calculation Interval : 1.26599999999996 ms to 16.26 ms





No.	Name	RMS	Angle	No.	Name	RMS	Angle
1	LINE_UL1	12.744(V)	0.0°	1	LINE_IL1	425.838(A)	0.0°
2	LINE_UL2	12749.02(V)	120.0°	2	LINE_IL2	180.671(A)	120.0°
3	LINE_UL3	12748.55(V)	240.0°	3	LINE_IL3	180.665(A)	240.0°
4	LINE_UN	12736.08(V)	180.0°	4	LINE_IN	245.169(A)	0.0°

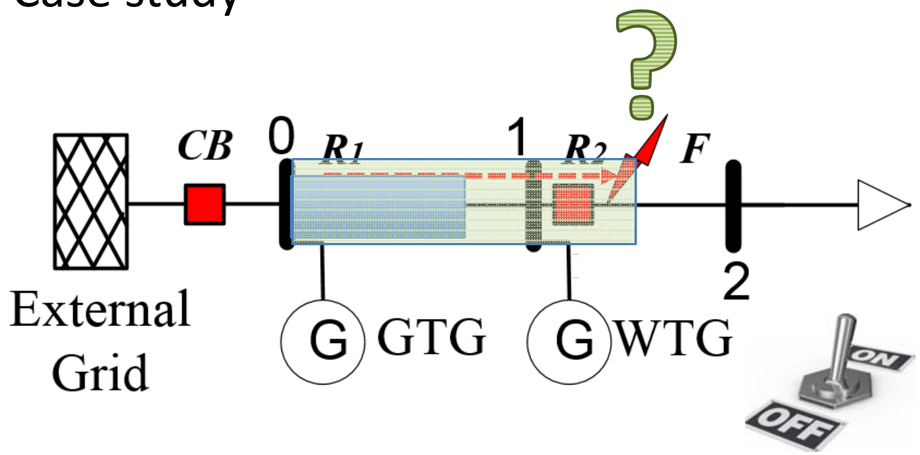
Events List

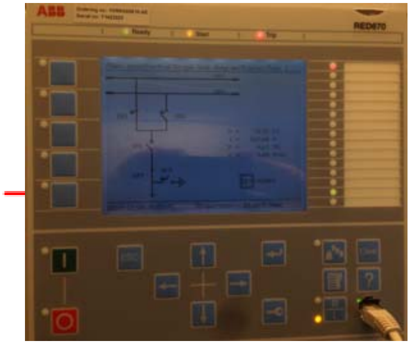
Channel Number	Name	Status	Time
1	TRIP L1	On	12/26/2014 7:01:16:891 AM
4	START L1	On	12/26/2014 7:01:11:891 AM

elay HMI

Adaptive distance relay testing

Case study



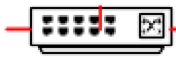


Setting group 1

RED 670

DG integration **VS** protection setting requirement

eMEGAsim simulator OP5600



IEC61850 based communication

Setting group 2

Ref.:

Z. Liu, H. K. Høidalen, An adaptive inverse time overcurrent relay model implementation for real time simulation and hardware-in-the-loop testing, DPSP 2016

Z. Liu, H. K. Høidalen, A. Ling, M. M. Saha, An adaptive distance relay model implementation for hardware-in-the-loop testing, PAC World 2016.

Conclusion and future possibilities

HIL testing is an excellent solution for advanced protection researches

- Increase simulation and testing speed
- Help researchers to improve their protective algorithms and devices
- Substation automation design based on communication protocols, e.g. IEC61850
- Scalability and flexibility allow adaptation to various study complexity and power system type and size.
- WAMS based applications, e.g. situation awareness, system protection and control, cyber security, etc.

It is a good platform to cooperate with utilities, academics and industries for knowledge sharing and updating as well as professional training.

Live case in the lab.
Meet you there ☺