PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

WP9 – Protection System Demonstration
Non-selective Schemes: Tasks 9.7/9.8

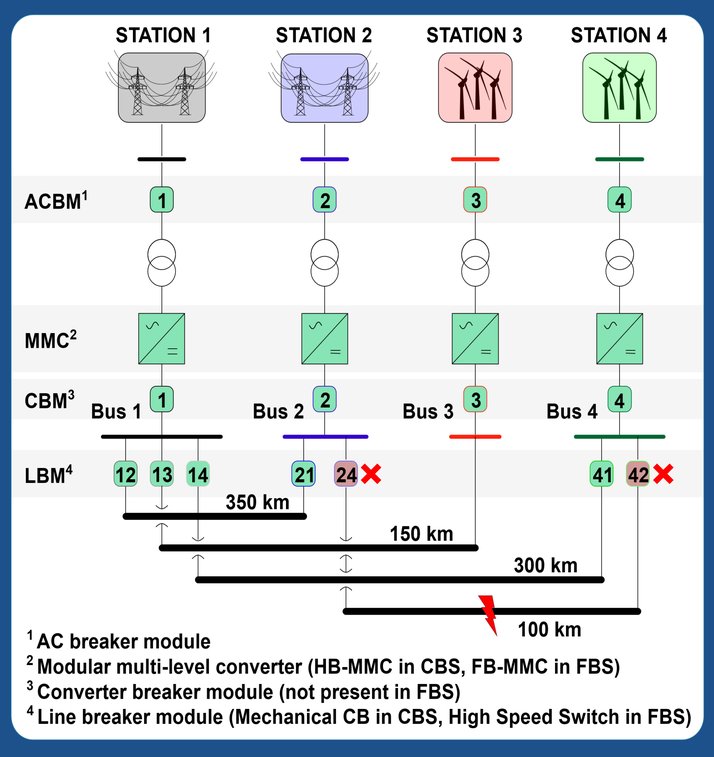
Work Package 9 represents the culmination and integration of a number of other work packages. A range of grid protection strategies and implementations have been taken from Work Package 4, where they have previously been verified using off-line simulation. The use of hardware in the loop techniques allows an opportunity to verify and increase the Technology Readiness Level (TRL) of the overall protection system.

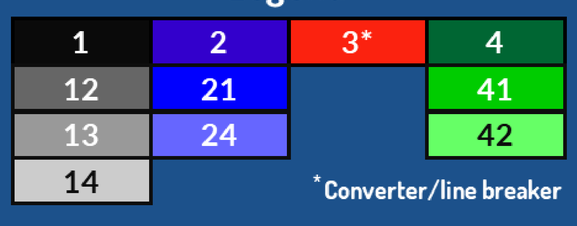
Scope

CBS Converter Breaker protection Strategy	FBS Full Bridge converter based protection Strategy
Asymmetric monopole	Symmetric monopole
Half-bridge MMC	Full-bridge MMC
Converter breaker	Fault current control
Mechanical DC breaker	High-speed switches

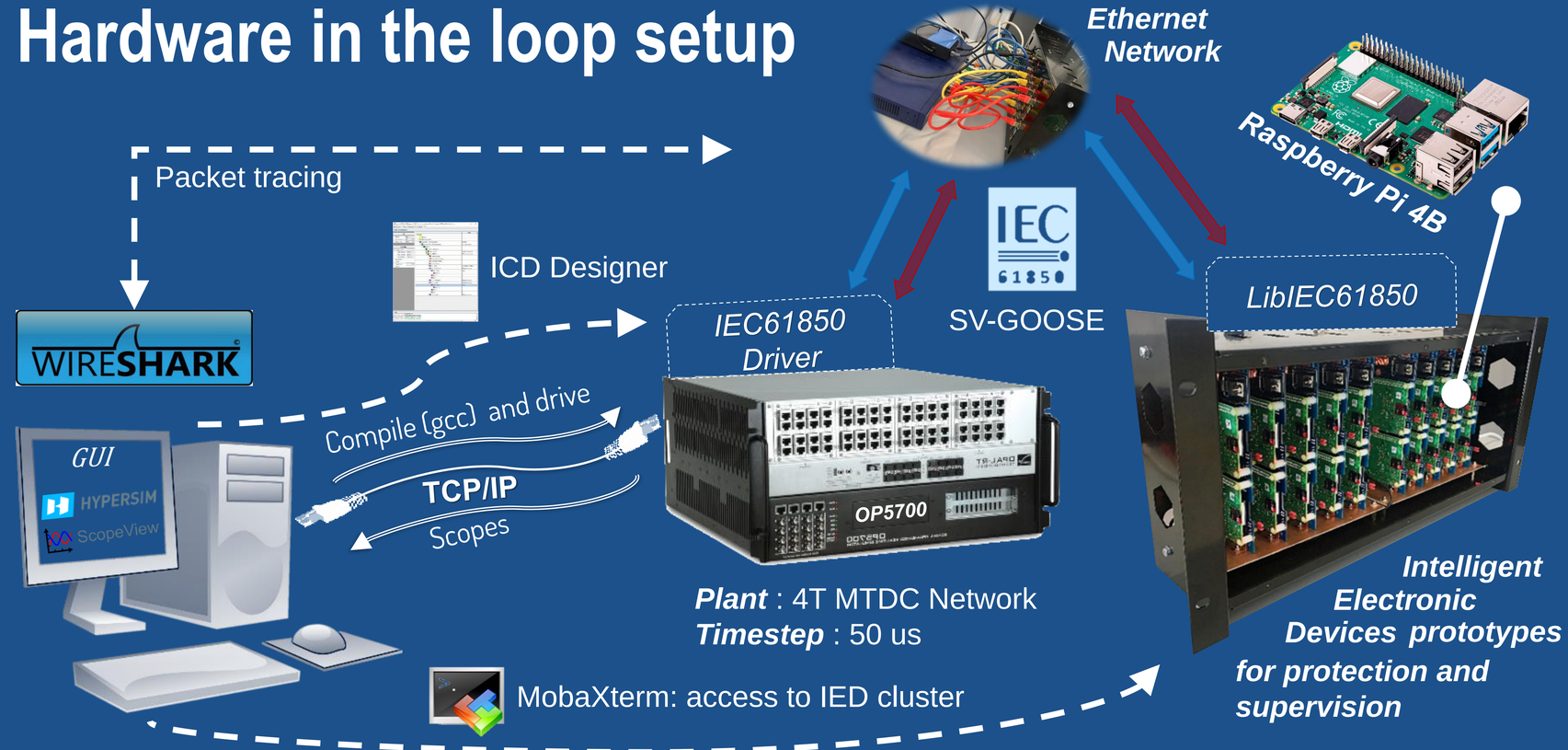
Two systems have been tested. One is a four terminal asymmetrical monopole to test the CBS strategy. This HVDC network has 11 mechanical circuit breakers per pole, 4 DC cables and 4 Half-bridge Modular Multi-level Converters. On the other side there is a four terminal symmetrical monopole for the FBS strategy. It has 4 Full-bridge MMCs, no DC breakers on the converter side but 8 high speed switches per pole are required to protect the system. About a thousand network elements and up to 2000 control elements were used from the HYPERSIM library.

Benchmark network



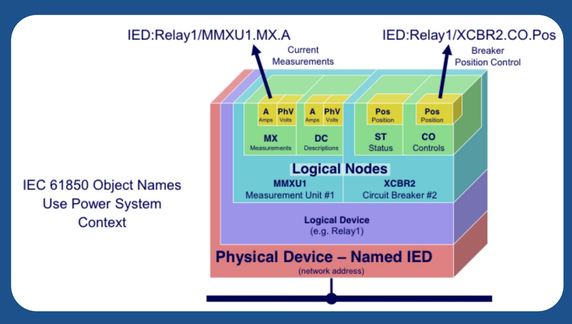


Hardware in the loop setup



Device under test: IED prototypes

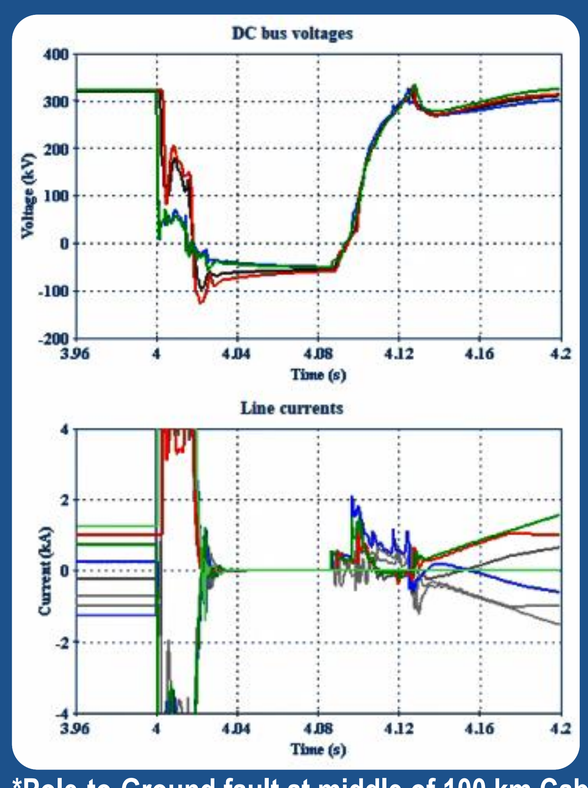
We used **Raspberry-pi** to prototype the **IEDs** and C code programming language because of its flexibility and execution speed. Also with a well-structured coding approach we can ensure modularity and ease the repetition and evolution of the program to be implemented in different kinds of IEDs. One of them is the protection IED. The C code was written based on specifications provided in WP4 or in Simulink blocks like in the FBS case. First we tested the program in HYPERSIM, so that the code runs in synchrony with the simulation, before putting the program in the RPI based IED for HIL tests. Similarly, we developed Supervision IEDs. Supervision algorithms are generated from SUPREMICA, a software to design automation systems using discrete event systems theory.



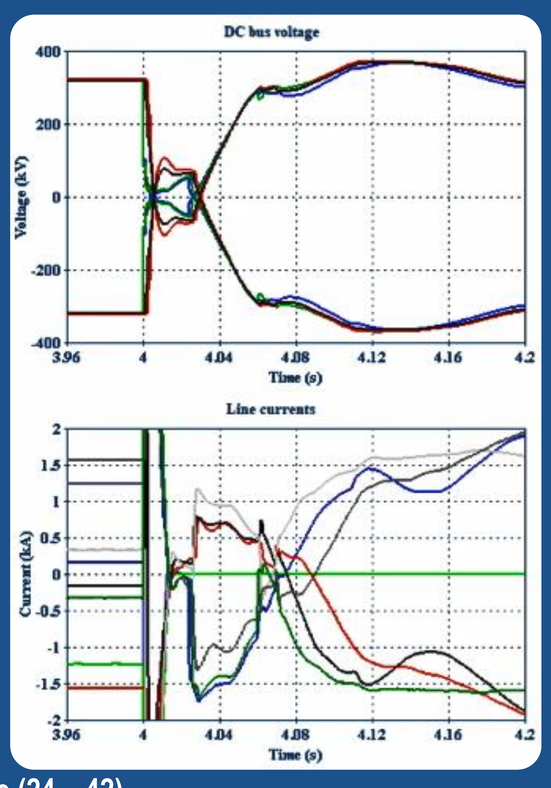
Industrial standard: IEC61850

IEC61850 is a standard meant to create an interoperable environment in digital substations. It is a fast Ethernet communication protocol, with satisfactory performances in terms of speed for the non-selective protection strategies. It's implementation was not straightforward: comprehension of the norm semantics is required as well as a clear definition of the functional architecture of the system.

CBS*



FBS*



*Pole-to-Ground fault at middle of 100 km Cable (24 – 42)

Achievements

- **HIL:** Protection and supervision IEDs tested
- **RTS model:** HVDC breaker and MMC models in Hypersim
- **Benchmark grid:** Two 4-terminal HVDC networks implemented
- **Sequences validation:** Primary and backup sequences validated
- **Interoperability:** Implementation of IEC61850 industrial communication protocol
- **Supervision:** System supervision designed, implemented and tested

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