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Virtualized wide-area protection, Anti-islanding protection using 5G communication

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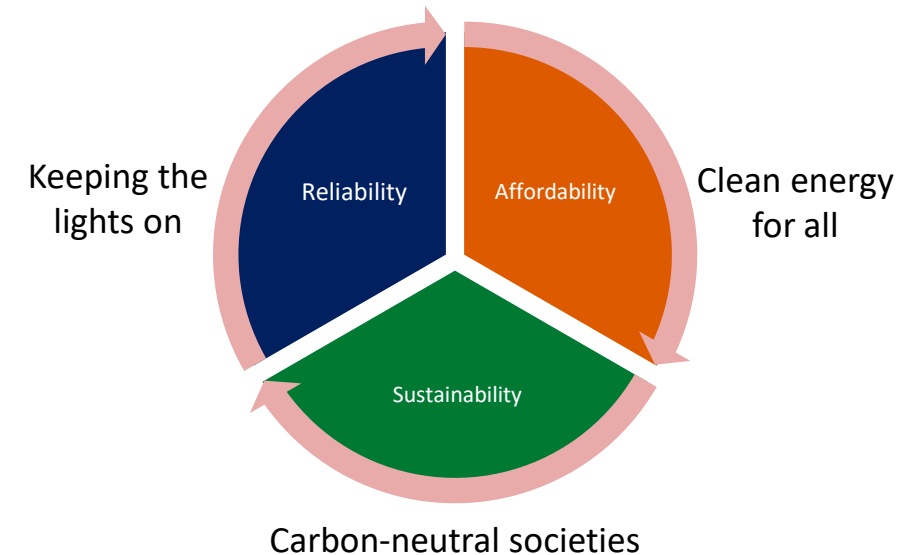
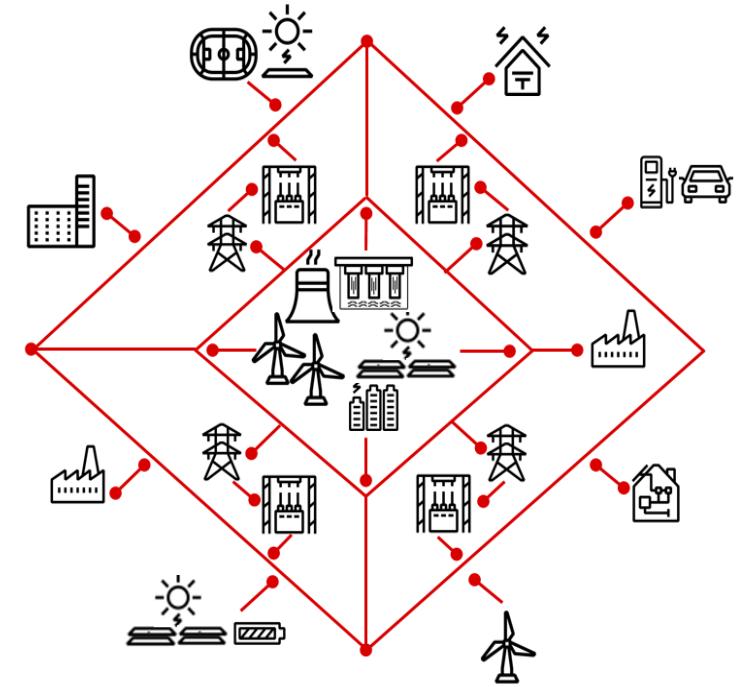


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- Motivation for the research
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Introduction

- Power system operators are looking to deploy novel intelligent solutions to maximize efficiency and reliability of the distribution networks
- Need for modernizing protection solutions to accommodate the distributed energy resources (DERs) without compromising safety
- Constellation is an innovation project initiated by UK Power Networks to develop and demonstrate decentralized protection and control architecture



Who is UK Power Networks?



8.4M homes and businesses

29% of UK Total

9.8GW Distributed Generation Connected

32% of UK Total

70,888GWh electricity distributed

28% of UK Total

UKPN motivation for the research

Keeping generation connected in a Net Zero future

Situation

Increased reliance on DSO services, such as Flexibility

Increased connection of low carbon generation and load

Solution roll out based on hardware installation

Complication

Unnecessary disconnection of DERs

Availability of network capacity

Scalability across a large network

UK Power Net - Network model

Main 1 – 33kV bus

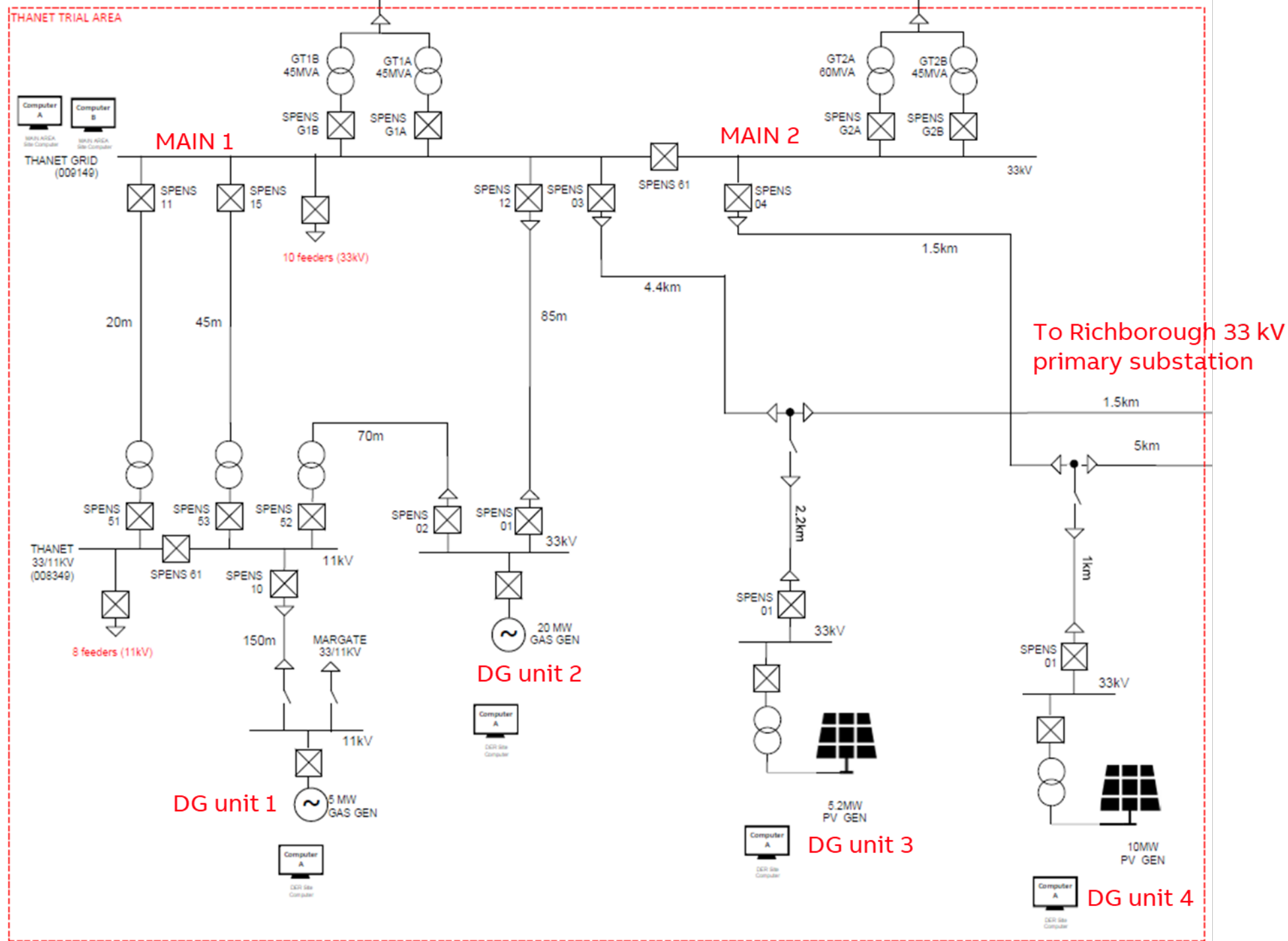
Main 2 – 33kV bus

DG unit 1 – 5MW gas gen

DG unit 2 – 20MW gas gen

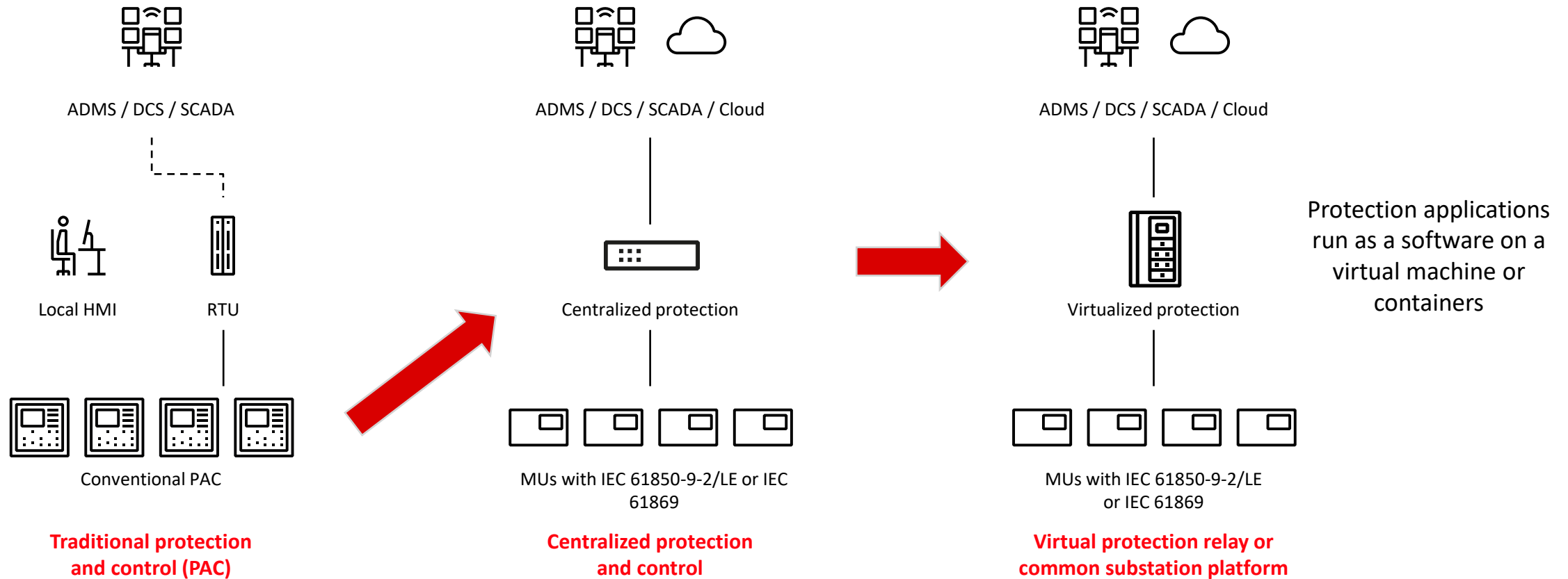
DG unit 3 – 5.2MW PV gen

DG unit 4 – 10MW PV gen



Virtualization of protection and control

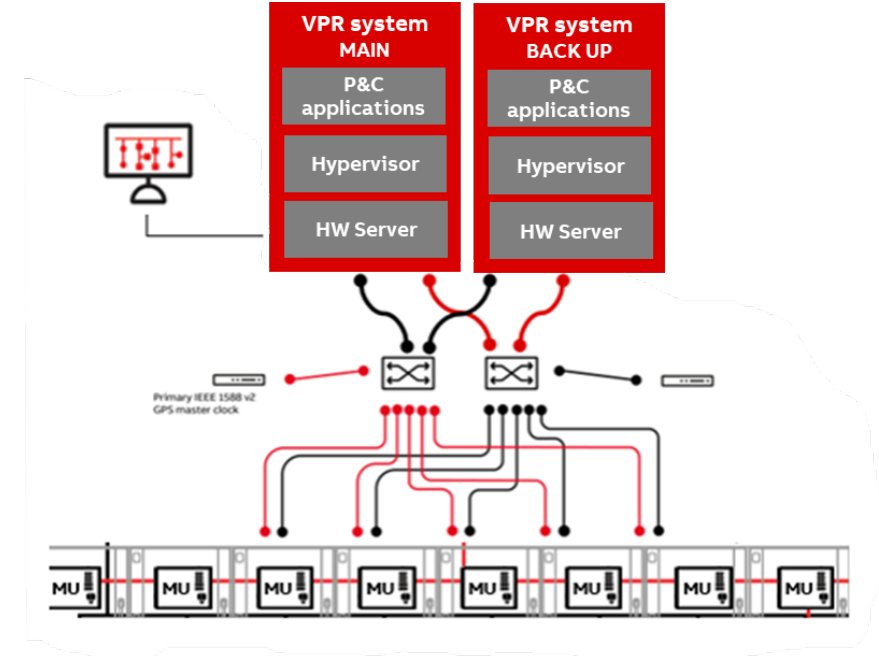
Next step in centralized protection and control



Virtualized protection requirements

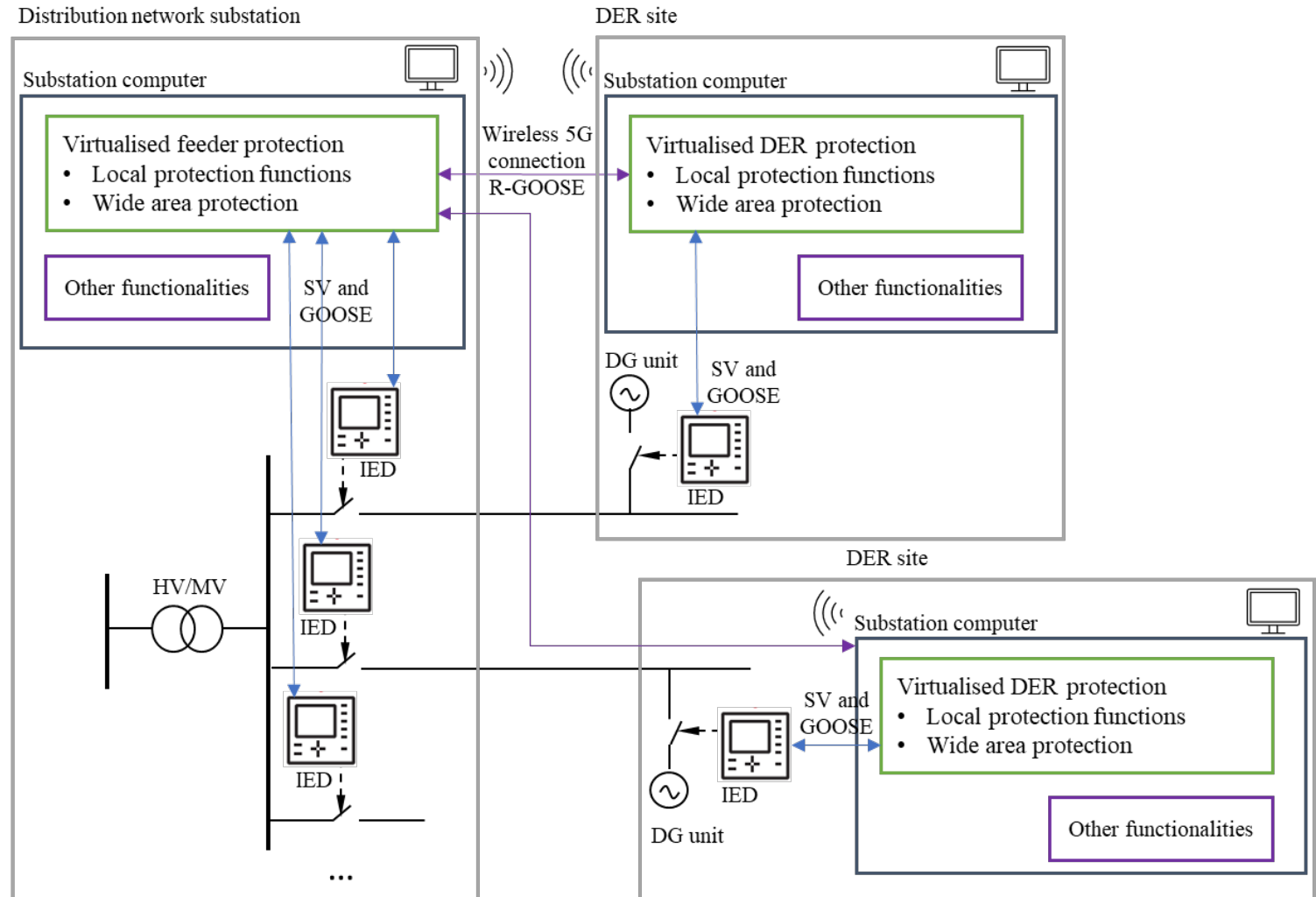
To guarantee real-time and reliable performance:

- Based on IEC 61850 standard
- Voltage and current Sampled Values from the MU are to be received with a consistent and low enough network latency
- Access to the computing resource must be available when the application needs it
- Accurate time synchronization using precision time protocol (PTP)
- Redundancy via parallel substation computers and parallel redundancy protocol (PRP)



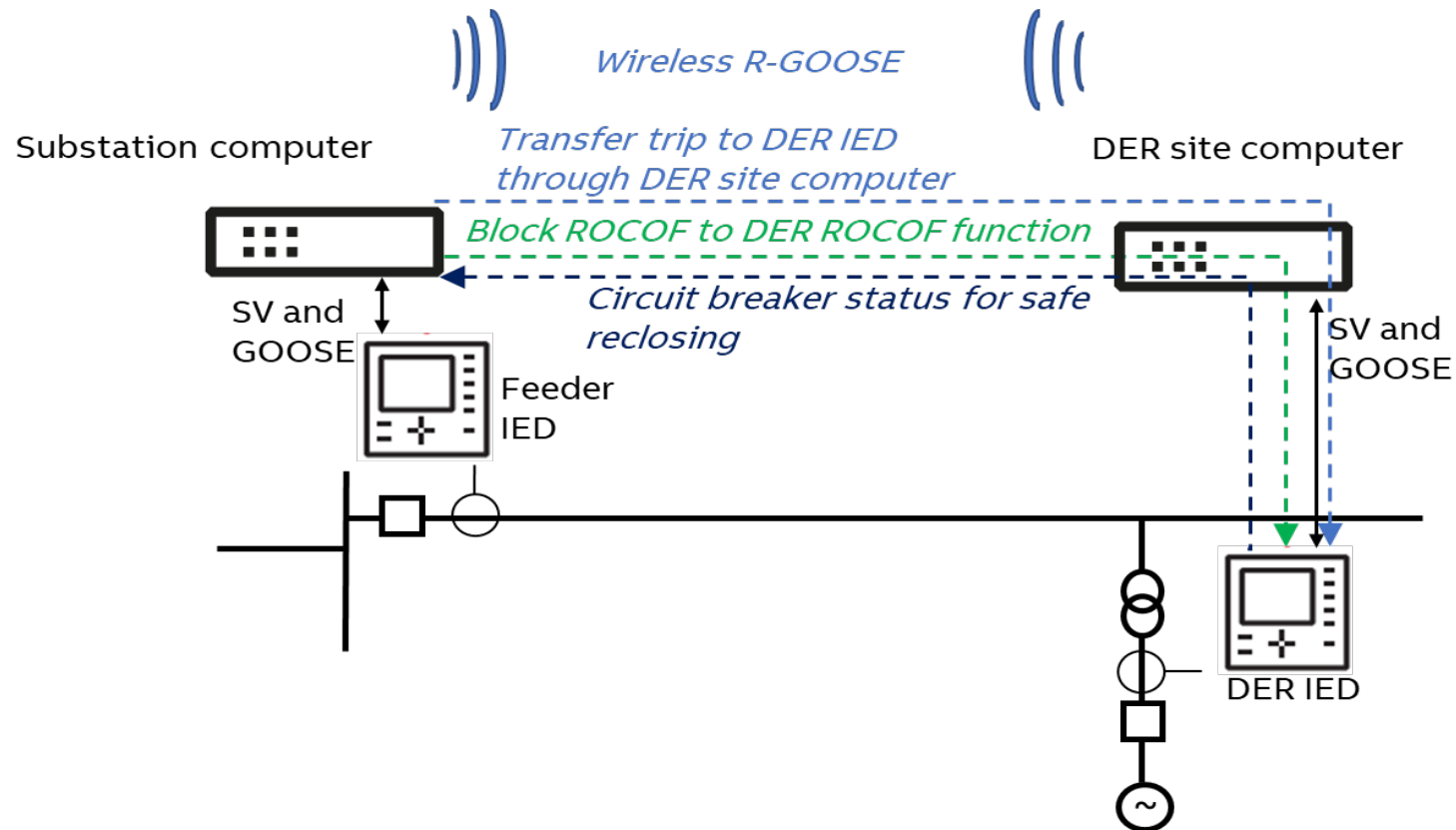
Proposed protection concept

- All protection functions are virtualized centrally in a substation computer
 - Virtualization software environment runs several applications in parallel
- IEDs at each bay act as the MU with back up protection enabled
- Protections include functions based on local measurements and inputs from multiple remote sites
- All information exchange in the WAP uses GOOSE, SV, R-GOOSE over 5G communication



Virtualized wide-area protection

- Dedicated ROCOF (LoM) protection is applied to prevent unintentional islanding
- Wide-area protection using R-GOOSE over 5G

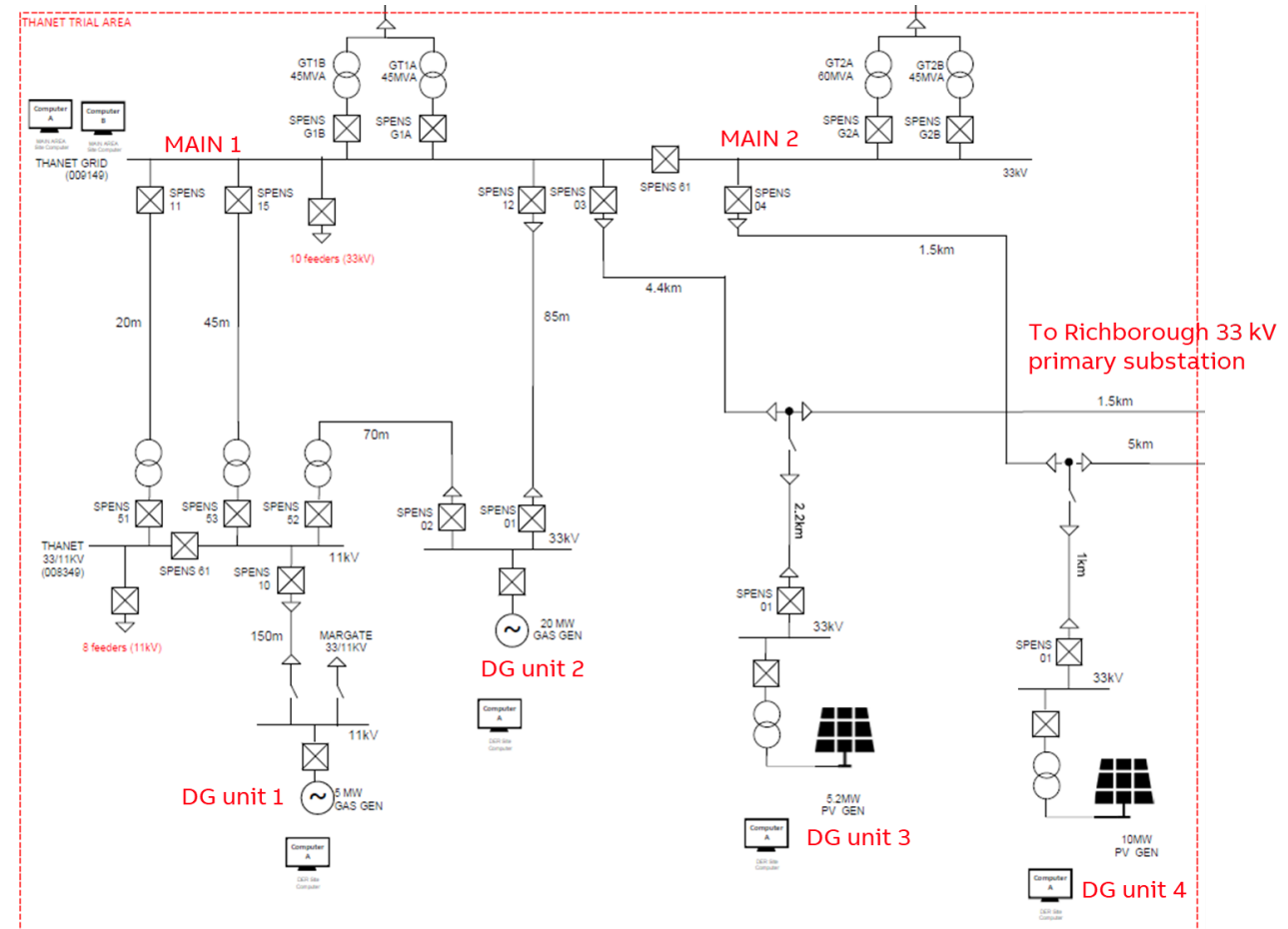


Simulation set up

Simulations focus on testing the operation of wide-area protection and communication supervision

RTDS simulates the R-GOOSE communication delay of the wireless 5G communication link. That is, the IEDs are not directly communicating with each other but only via RTDS

Communication between RTDS and devices via 61850-8-1 GOOSE.T

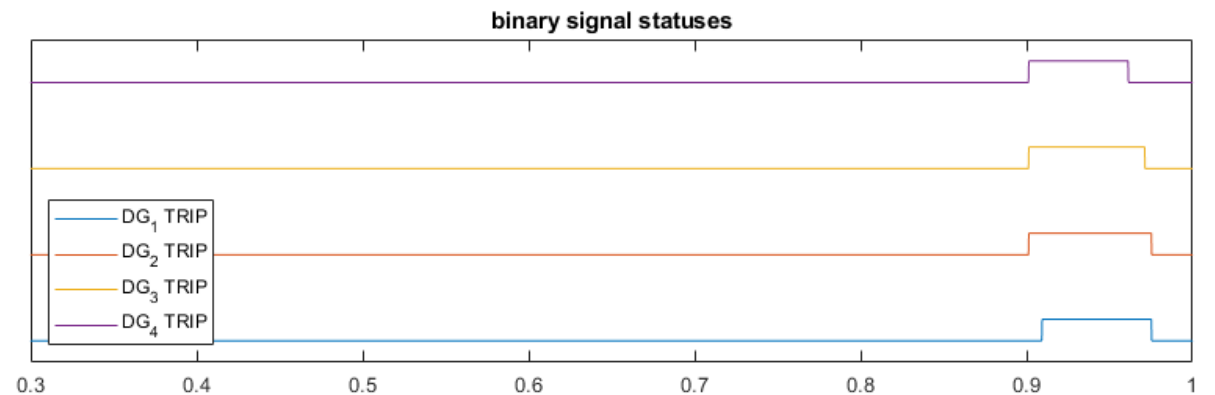
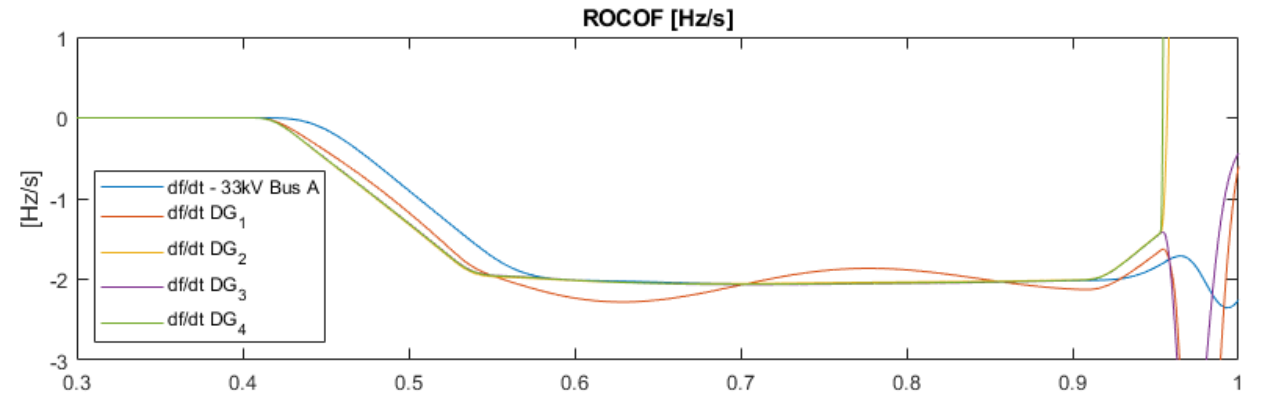
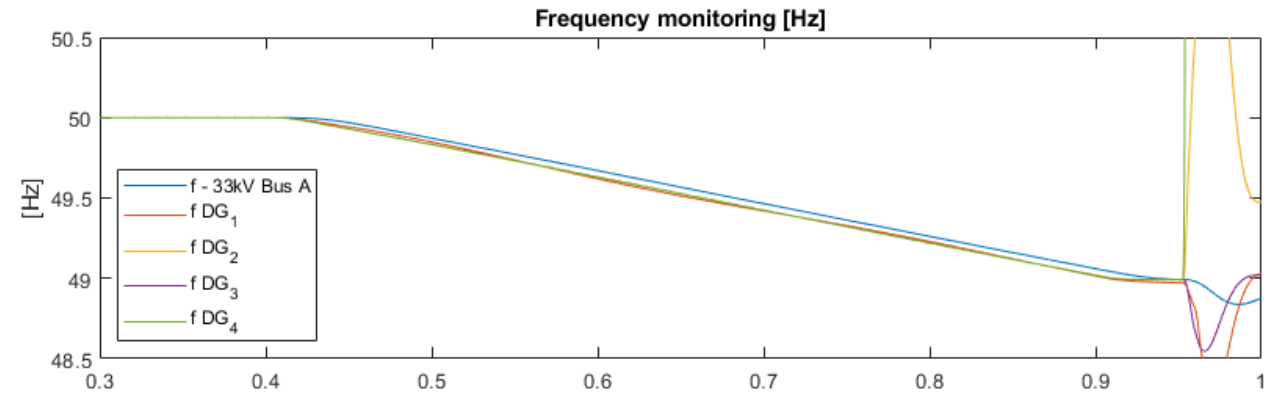


ROCOF simulation

- unwanted tripping

Local ROCOF based blocking

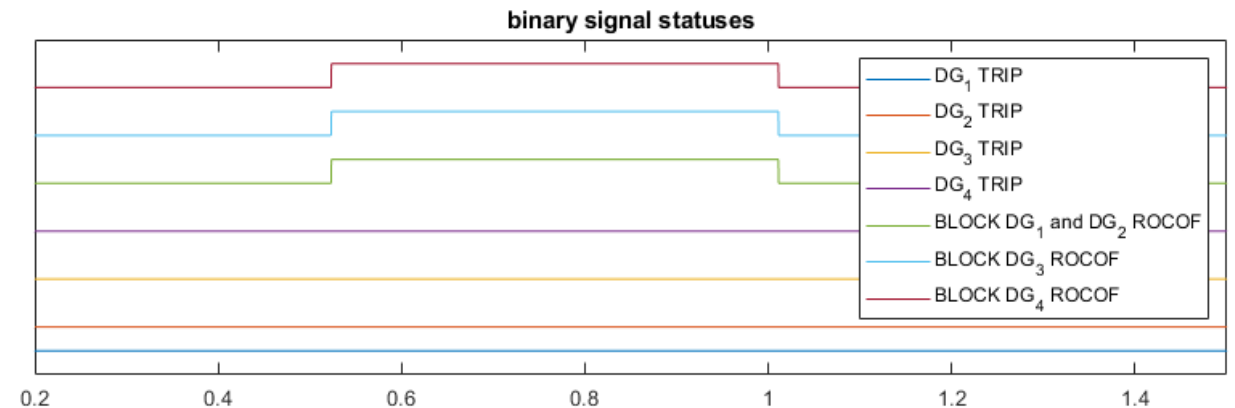
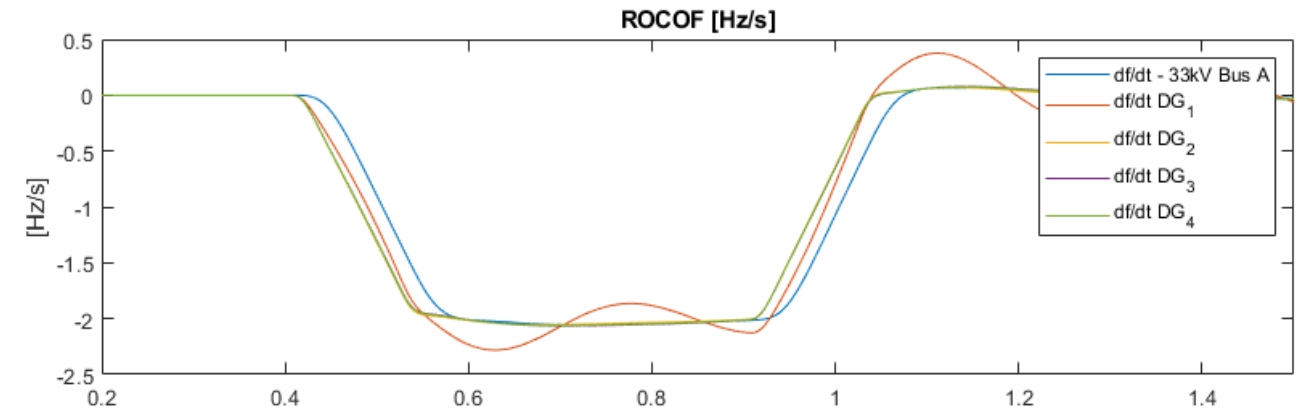
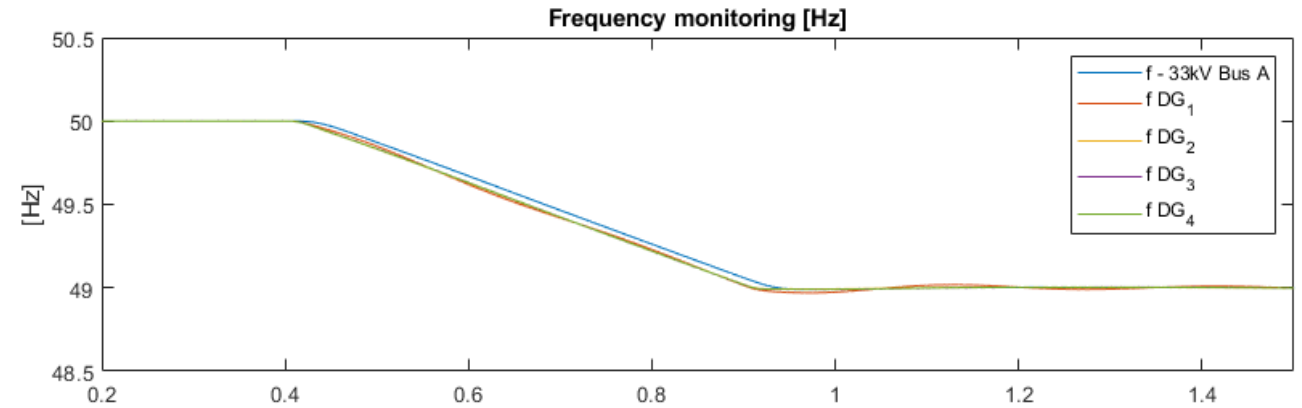
- System frequency decreases from 50 Hz to 49 Hz at a rate of change of -2 Hz/s
- Consequently, all four DG units in the examined system see a ROCOF of approximately -2Hz/s
- The local ROCOF-based anti-islanding protection is triggered
- The blocking is not effective resulting in all four DG units to trip falsely



Wide area ROCOF based blocking

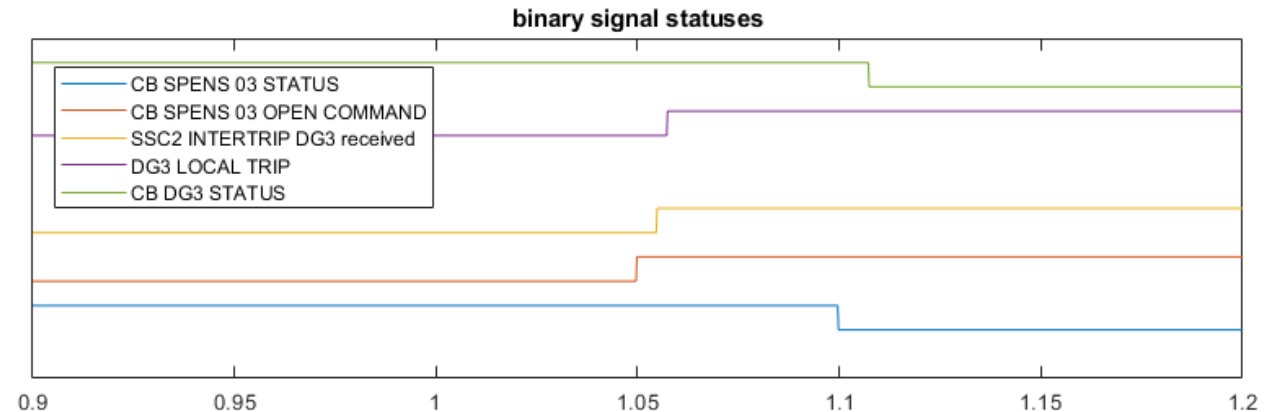
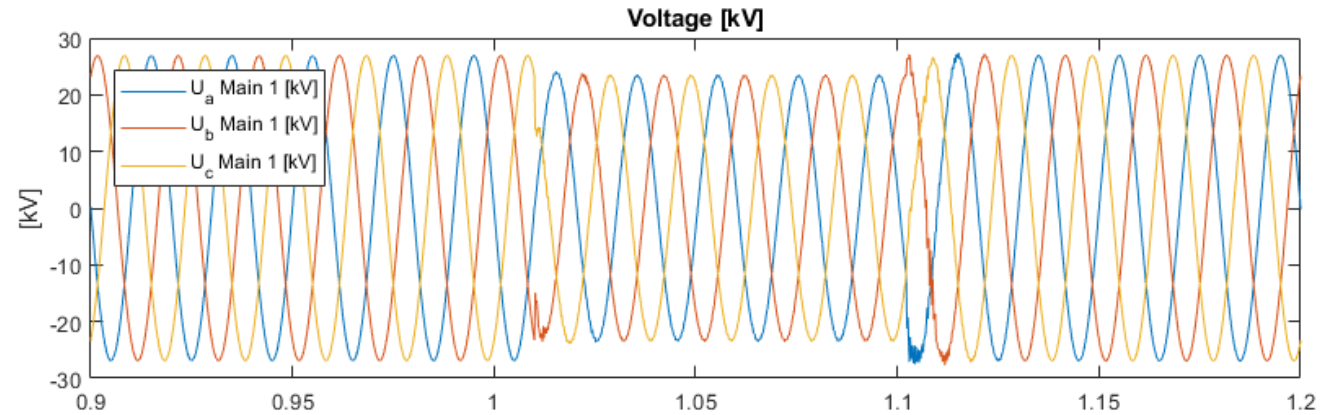
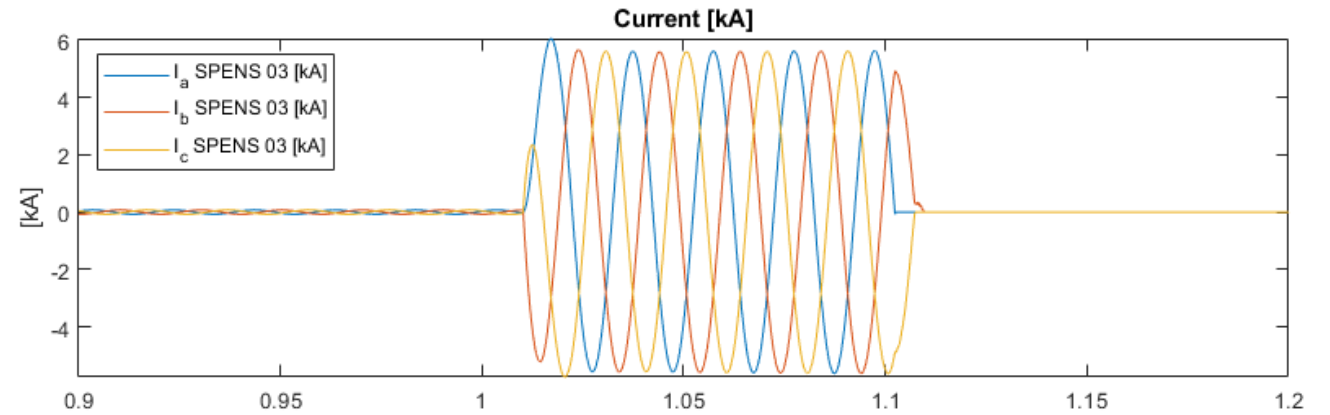
Prevents unwanted tripping

- Wide area detection logic was enabled
- This time the wide area disturbance is detected by the primary substation IED, which in turn sends blocking messages via R-GOOSE to all four DG units.
- Consequently, no unwanted tripping occurred



Transfer trip over 5G communication

- Three-phase short circuit occurs at the beginning of the outgoing feeder SPENS 03 (DER unit 3 is connected to this feeder)
- SPENS 03 CB trips
- Main substation computer sends transfer trip signal to DER site computer via 5G communication
- DER site computer issues trip command to DG3 CB
- DG3 CB opens



Conclusion

- Protection and control need to be modernized as the amount of DERs increases day-by-day
- Wide-area protection concept utilizing virtualization and wireless 5G communication has been developed to enhance system resiliency
- The wide-area protection ensures:
 - Prevention of unintentional islanding
 - Unsynchronized reclosing
 - To keep the DERs connected during system-wide disturbances
- Correct operation of the wide-area protection functionality has been verified in the lab
- Next steps of the Constellation project include integration testing in the lab and field trials

QUESTIONS?