13TH OF DECEMBER 2023

Digitalisaation merkitys vihreän siirtymän edistäjänä

Constellation-innovaatioprojekti

ABB

Energy system in transition

Several significant, interlinked global development drivers affecting the energy system simultaneously

Climate change requires immediate actions. Paris climate agreement sets very ambitious targets (Europe climate neutral by 2050) and even this will not be adequate.

War in Ukraine means a paradigm change for the whole energy system and will accelerate the green transition but also means real challenges.

Renewable generation (wind, solar) already now the least cost alternative for new electricity production. Intermittent and often distributed.

Electric vehicles becoming the mainstream solution in the near future. Clean, significantly higher energy efficiency and significantly lower maintenance needs. “Mobile energy storages”.

Energy storages are becoming or already are economically feasible.

Digitalization is proceeding, costs for IoT devices enabling real-time monitoring and control are decreasing and new enabling technologies are emerging.

Energy system in transition

Need for innovation higher than ever

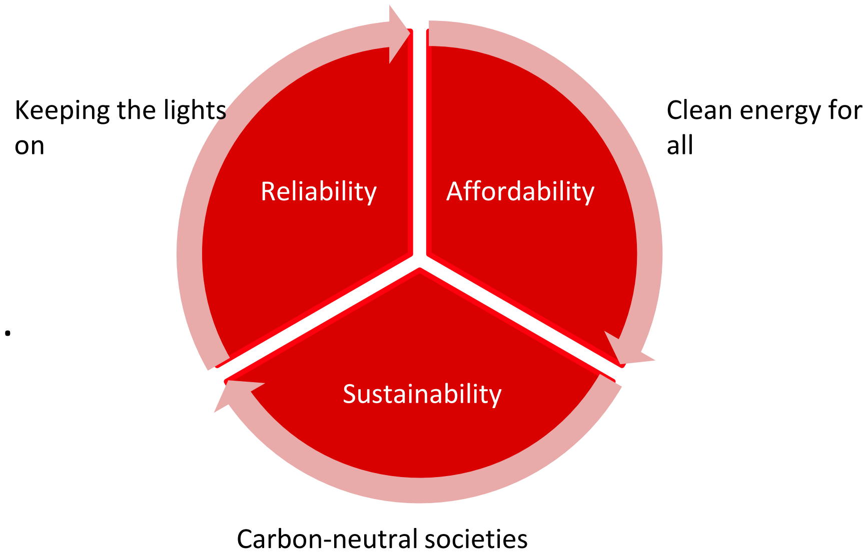
To reach the **sustainability** goals the following needs to happen very fast:

- Fully carbon-neutral energy
- Electrification of society

But we cannot compromise on **reliability** and **affordability** either.

⇒ The energy system is becoming more complex and dynamic than ever before.

⇒ New business opportunities and roles will arise.



Control and protection principles of electrical grids are drastically changing

Where 5G could be of use?

- Distributed energy resources (generators, new types of loads and energy storage units) are being connected to distribution networks
  - Assumption of unidirectional power flow is no longer valid
  - Loading patterns change
  - Controllable resources also beyond the primary substation
- The costs for IoT devices are decreasing

⇒ Real-time monitoring and control expanding to previously passive distribution networks

- Reliable but at the same time affordable communication infrastructure is an enabler for many smart grid use cases

- Smart grid use cases in which 5G could be used include e.g.
  - Protection applications
  - Congestion management (voltage control and prevention of overloading)
  - Utilizing DERs located in distribution networks for frequency control
  - Gathering data from various locations e.g. for predictive maintenance purposes

Protection applications and 5G

Requirements and observations

Communication requirements in protection applications

- Failure in the operation of protection can compromise the safety of the electrical grid and people
- Protection applications such as differential and intertrip protection have extremely strict requirements for latency, jitter and reliability
  - In many cases same requirements for down- and uplink
  - Number of devices is limited and the data amounts are usually relatively small
  - Average latency is not interesting, maximum latency is
- More relaxed real-time requirement for some other protection applications such as distributed generation loss-of-mains protection but reliability still needs to remain high
- Also applications with softer real-time requirements but high amount of data are likely to locate in the same area (e.g. fault location applications) → mixture of 5G services needed to meet requirements of different applications

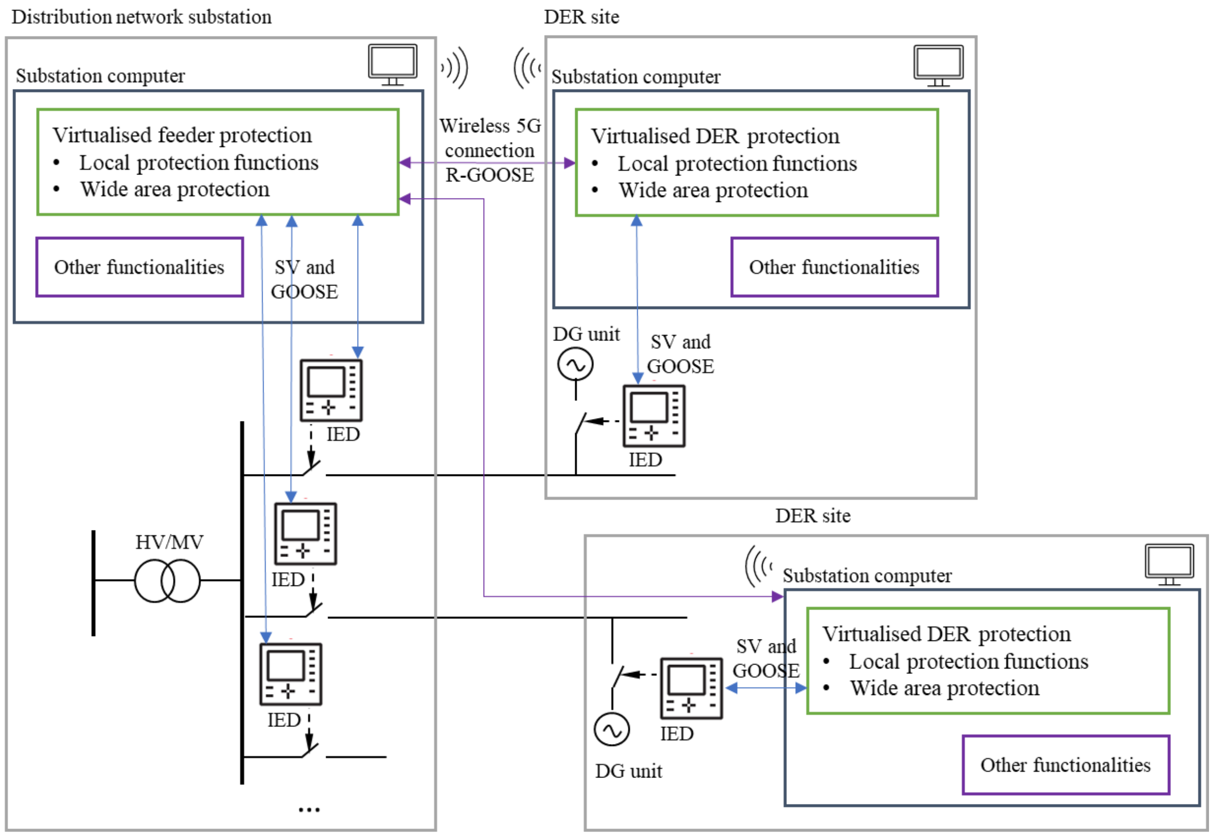
Some observations so far

- Performance of 5G NSA network has been stabilizing and can be used for the less demanding protection applications
- 5G SA network reaches closer to the communication requirements of the demanding protection applications but has not reached the limit yet
- If(when) operation of the communication network has been optimized for streaming services, the following might occur:
  - Messages are buffered at base stations and arrive in chunks. This is not well aligned with the IEC 61850 based GOOSE protocol operational principle of using re-transmission for enhancing reliability.
  - Down- and uplink have very different characteristics. Many protection applications need same characteristics to both directions.
- Communication protocol can affect the performance of wireless connections depending e.g. on the length of the packets and how the communication network is configured

Constellation innovation project

Project objectives

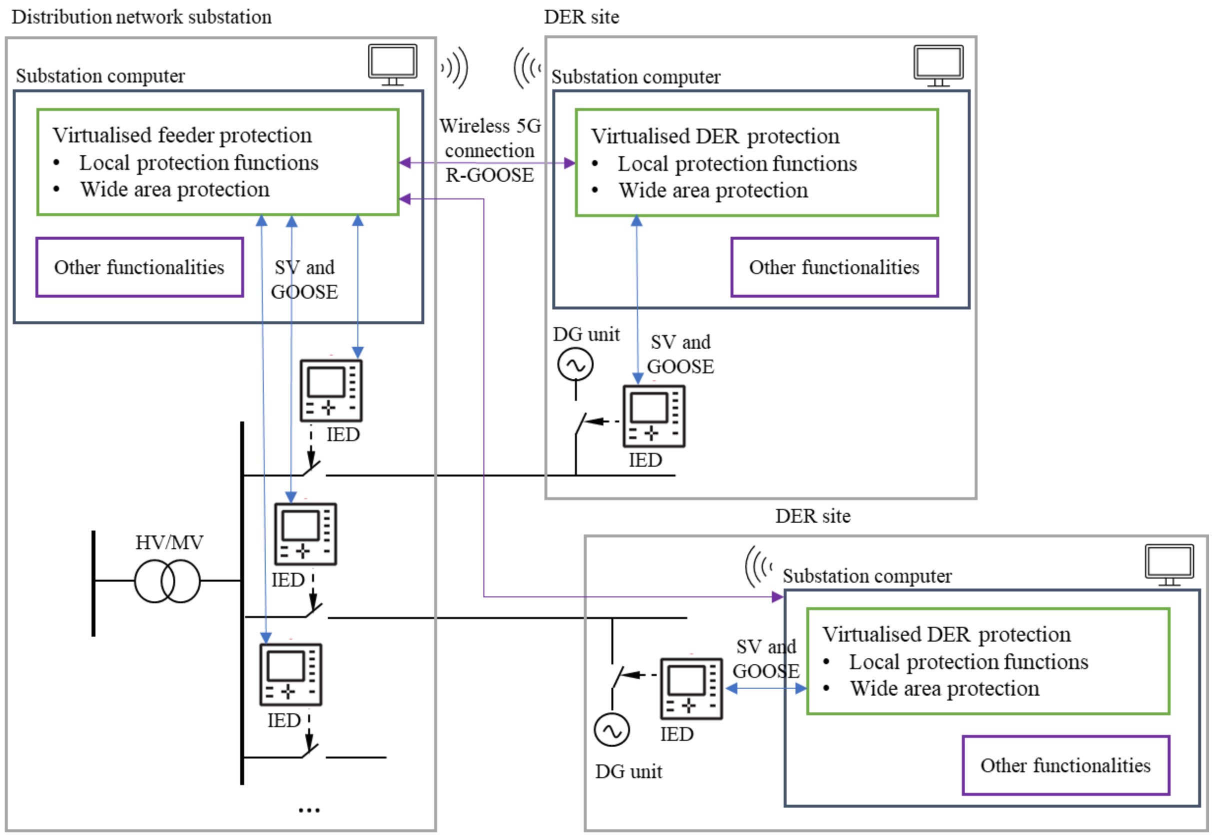
- To develop the architecture needed to introduce new type of intelligence to substations and DER sites
  - Virtualisation platform for local intelligence
  - Communication architecture
- To develop and demonstrate two distinct methods:
  - Wide area adaptive protection that aims to keep DERs connected through events occurring elsewhere in the network
  - Local ANM that aims to maintain the optimal DER asset operation during events when the central ANM is unavailable



Virtualised centralized protection concept

Constellation project

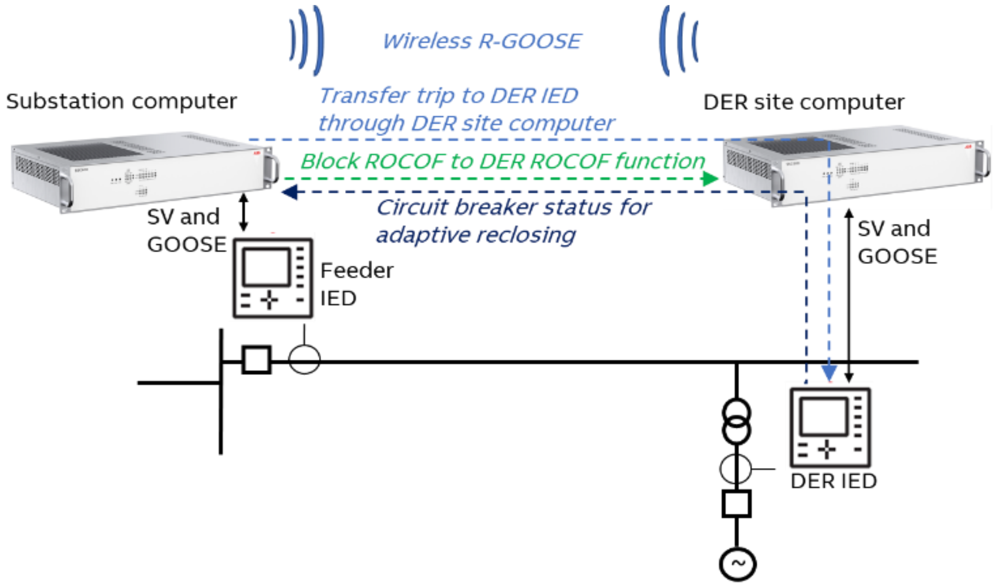
- All protection functionality is centralized on a substation computer at each main area and DER site
  - The substation computer hosts a virtualization software environment on which several applications exist in parallel
- IEDs at each bay act as an interface that receives process data such as measurements from instrument transformers and switchgear alarms and indications
- Protection functionality includes functions based on local measurements and functions utilising inputs from multiple remote sites
- All information exchange in the wide-area protection is IEC 61850 compliant



Wide-area protection functionality utilizing 5G

Constellation project

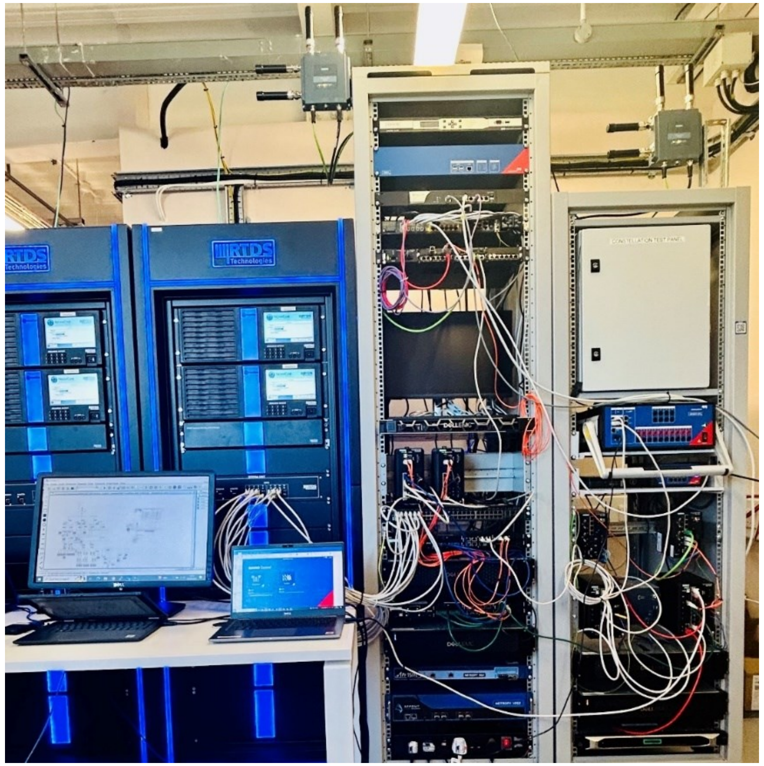
- Prolonged islanding is not allowed in the distribution networks and dedicated loss-of-mains (LoM) protection is used to prevent unintentional islanding
  - Currently, the most widely used LoM protection method is rate of change of frequency (ROCOF) protection based on local measurement at the generator site
- The wide-area protection functionality enhances the operation of LoM protection through utilizing R-GOOSE messaging over 5G between the main area and DER sites and implements the following functionality
  - Intertrip based on circuit breaker position information
  - ROCOF based blocking based on main area site ROCOF
  - Auto-reclose blocking to prevent unsynchronised reclosure of the feeder CB
  - Communication supervision



Communication requirements and status of 5G testing

Constellation project

- Communication requirements for the wide area protection are relatively relaxed since
  - there is also local ROCOF protection operating as backup LoM protection, and
  - communication supervision has been implemented to prevent using too old messages to block the local ROCOF
- The performance of the 5G slice will, however, be monitored during the trials which enables evaluating its suitability also for more demanding use cases such as differential protection
- 5G links have been established to the trial areas in UK Power Networks's distribution network and at PNDC lab site
  - Initial testing has been conducted but testing with real data (right protocols etc.) is only starting



Conclusions

- 5G can provide a cost-efficient communication infrastructure for several smart grid use cases if it fulfills the promises for real-time operation and reliability
- Energy (and other industrial) use cases have specific requirements that are to some extent contradictory to the needs of normal consumers using streaming services etc.
  - For latencies, the maximum value is important, not the average
  - Similar requirements for down- and uplink and also the amount of data can be similar to both directions
- The current 5G implementations can be adequate for less demanding smart grid use cases but the most demanding applications such as differential protection remain infeasible for now
- At the moment, there is a need to build separate communication supervision functionalities to supervise the status of the wireless 5G link. If the 5G network could provide information on its state, this would not be needed anymore.
- Accurate time synchronization service over 5G would bring alternative and cost efficient solution instead of local GPS to PTP service

ABB