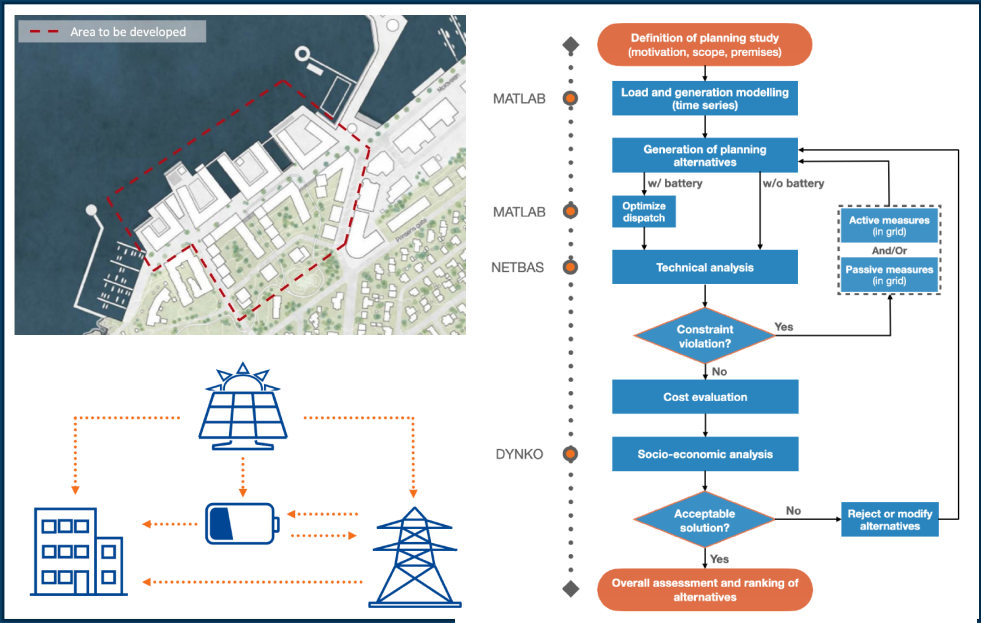
CINELDI Results 2021

CINELDI result: Practical application of active distribution grid planning to pilot area with new energy solutions (WP1)

Challenge and objective:

- Molobyen is a near-zero-emission-neighbourhood development area in Bodø considered in a pilot project together with the local grid company Arva.
- Grid-connection planning must consider the interplay with solar PV and district heating (DH).



Work performed:

- In a master thesis, CINELDI's active distribution grid planning framework is adapted to incorporate load and generation modelling from FME ZEN, a model for optimal operation of neighbourhood batteries, time series power flow analysis with NETBAS, and optimal grid planning with the DYNKO tool.

Significant results:

- Because of the DH supply, PV generation becomes the dimensioning factor for the distribution grid.
- Calculations of the cost of losses had to be adjusted to account for the effect of local PV generation.
- Neighbourhood batteries were not cost-effective, depending on transformer overloading restrictions.

Impact for distribution system innovation:

- Grid planning must consider the design of the internal energy system in neighbourhoods and the coordination with other energy carriers/sources.

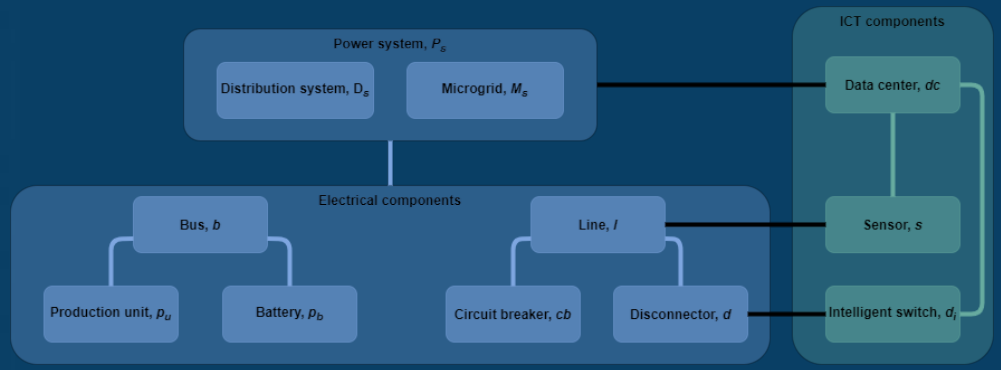
Reference in CINELDI:

- E. Øye: "A Practical Application of an Active Distribution Grid Planning Framework in Relation to a Pilot Area for New Energy Solutions", MSc-thesis, NTNU, 2021.

CINELDI result: Simulation tool for reliability evaluation of modern distribution systems (WP1)

Challenge and objective:

- With the increasing penetration of renewable energy resources, flexible resources, and ICT components in the distribution system, system behaviour will change. Reliability calculations must be modified to include the new components and to consider the distribution system as an active network.
- The tool aims to calculate the reliability in an active and smart distribution system including ICT components, distributed generation, and flexible resources



Work performed:

- Developed a tool package in Python for calculating reliability in an active distribution system including flexible resources and distributed generation.

Significant results:

- A reliability assessment tool for modern distribution systems.

Impact for distribution system innovation:

- A foundation for the reliability assessment of modern distribution systems. It can support the reliability analysis of a cyber-physical distribution system with active components.

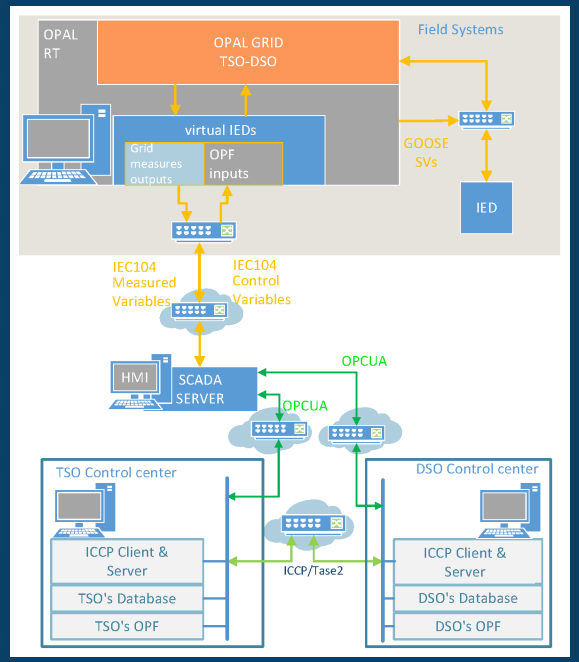
Reference in CINELDI:

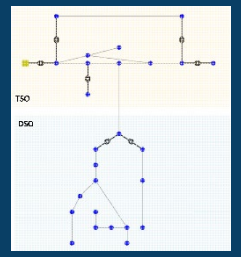
- S.F. Myhre, O.B. Fosso, P.E. Heegaard, O. Gjerde: "A Reliability Assessment Tool for Smart and Active Distribution Systems – RELSAD", paper PSCC, 2022.

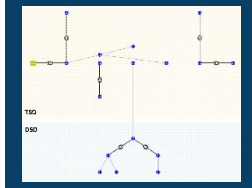
CINELDI result: Study operational coordination between TSO and DSO (WP2/WP3)

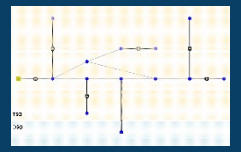
Challenge and objective:

- Study the level of details in grid model and measurement data exchanges needed for operational level coordination between TSO and DSO.









Architecture of laboratory setup (left). Ful DSO grid model (top), technologically clustered DSO grid model (middle), DSO grid model as a P-Q bus (bottom)

Work performed:

- The challenges in near real-time network model and data exchanges between TSO and DSO control centers are investigated for a coordinated TSO-DSO reactive power management use case.
- A realistic ICCP/TASE 2 protocol is implemented in laboratory environment where the physical network is simulated in a real-time simulator while optimal set-points are communicated from the control centers to simulated assets using IEC 60870-5-104.
- Three equivalet grid models of the DSO network are compared for TSO operations.

Significant results:

- The DSO equivalent grid models should be developed with a tailored approach for the dynamics considered in specific cases to avoid performance degradation.
- The use of the CGM model for exchanging different levels of DSO equivalent grids has showed its adequacy for such operational coordination.

Impact for distribution system innovation:

- A laboratory testsystem is developed in NSGL which can be used to validate different usecases of TSO-DSO operational coordination.
- With this work and with its next activities, DSOs will be able to prepare and model data (especially flexibility related) required for operational coordination with neighbouring DSOs as well as the TSO.

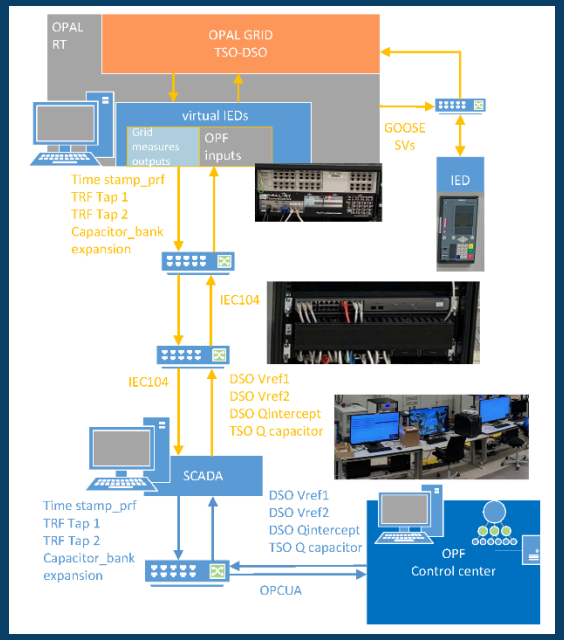
Reference in CINELDI:

- M.Z. Degefa, H. Lundkvist, S. Sanchez-Acevedo, K.N. Gregertsen: "Challenges of TSO-DSO Voltage Regulation Under Real-Time Data Exchange Paradigm". A paper is submitted and under review in IEEE Transactions on Smart Grid.

CINELDI result: Testbed for Advanced Distribution Management Systems: Assessment of Cybersecurity (WP2)

Challenge and objective:

- Establish a cyber-physical ADMS testbed to address research questions on benefits and cyber security vulnerabilities of advanced distribution network operation functions.



Architecture of laboratory setup

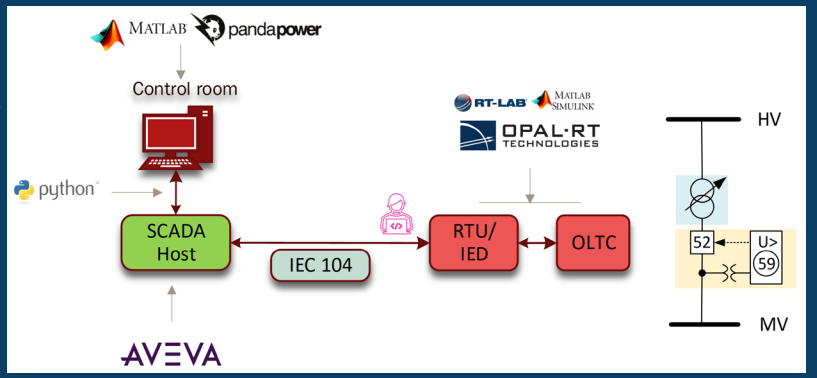
Work performed

- Initial implementation of cyber-physical testbed for Advanced Distribution Management System (ADMS).

Significant results:

- The testbed is used for cybersecurity assessment of smart power distribution network operation use case of TSO-DSO coordinated reactive power management. The functioning of the first implementation of the c testbed is validated.

Demonstration of smart operation vulnerabilities.



Impact for distribution system innovation:

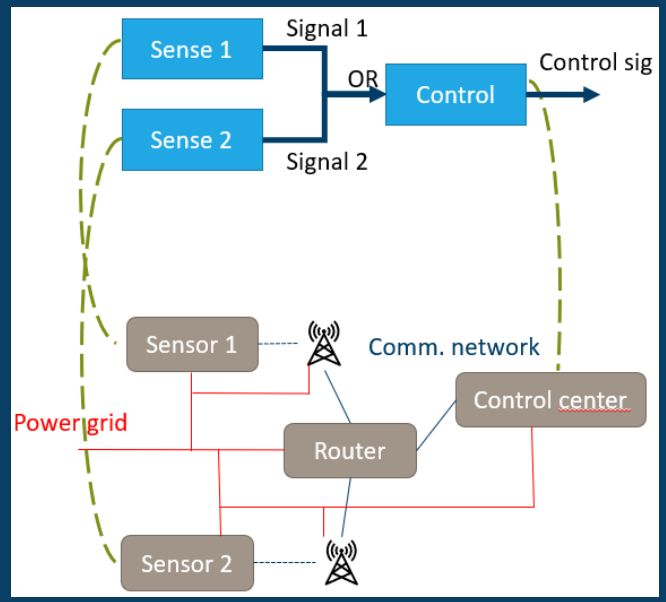
- The testbed can be customized and scaled up to DSO needs to test relevant SCADA/DMS functions.

Reference in CINELDI: M.Z. Degefa, S. Sanchez, R. Borgaonkar: "A Testbed for Advanced Distribution Management Systems: Assessment of Cybersecurity", 2021 IEEE PES Innovative Smart Grid Technologies Europe (ISGT Europe) (pp. 1-5). IEEE. Presented and published.

CINELDI result: Modelling framework for study of the differences between centralized and decentralized smart grid services (WP2)

Challenge and objective:

- Performing reliability analysis of interconnected smart grid system services.
- Taking into account common dependencies on both power system and ICT infrastructure.
- Investigate differences in services deployment: centralized and decentralized operation.



Work performed:

- Created a simulation framework for evaluating reliability of system services in a smart distribution grid.
- Performed a test using the IEEE 33-bus test grid.

Significant results:

- Trade-off between centralized and decentralized service deployment can be quantified
- Decentralized availability is better on average, but can vary throughout the grid.

Impact for distribution system innovation:

- Step towards reliability analysis that more accurately considers impact of ICT infrastructure and different deployment options.

Reference in CINELDI: F.B. Haugli, P.E. Heegaard: "Modeling framework for study of distributed and centralized smart grid system services," 2021 IEEE International Conference on Communications, Control, and Computing Technologies for Smart Grids (SmartGridComm), 2021, pp. 321-326.

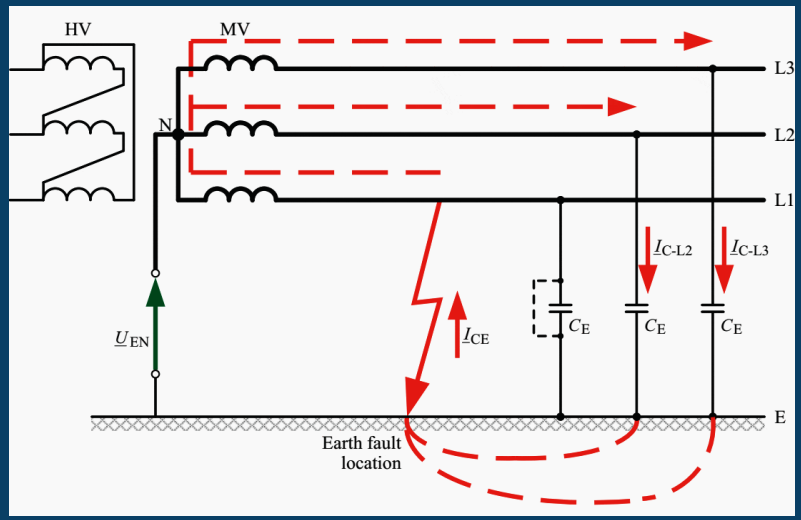
CINELDI result: Single line to ground-fault locations method developed and tested in simulation (WP2)

Challenge and objective:

- Unlike short circuit faults, there has not been a well-established method for detecting and locating single line to ground (earth) faults in isolated systems.
- Development and test of earth fault location method for ungrounded distribution networks. The method shall be cost effective, simple to implement and its accuracy shall not be affected by variation in measurement inaccuracy, load situation, fault resistance etc.

Work performed:

- Two novel current based methods for locating earth faults in isolated closed ring operating MV networks were developed.
- The methods are based on utilising zero and negative sequence current during fault on ring connected feeders.



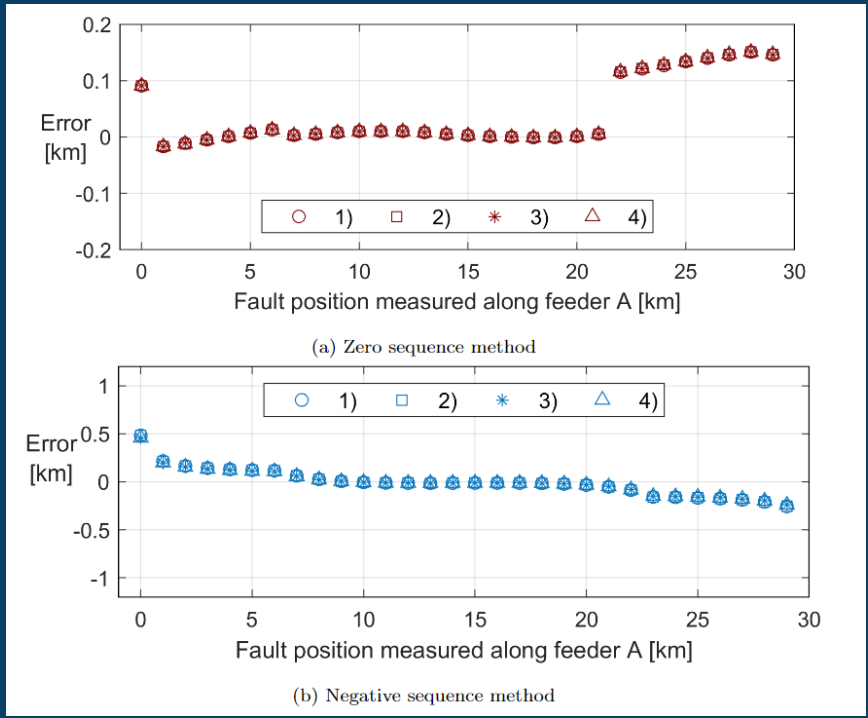
Reference in CINELDI:

- T.A. Zerihun, T. Treider, H. Taxt, L.B. Nordevall, T.S. Haugan: "Two novel current-based methods for locating earth faults in unearthed ring operating MV networks", submitted to ELSEVIER/EPSR 2021, and under review.

CINELDI result: Single line to ground-fault locations method developed and tested in simulation (WP2)

Work performed:

- The performance of the methods were investigated by conducting multiple simulation tests considering variation in measurement inaccuracies, load, fault resistance, and other parameters.



Significant results:

- During the simulation tests, both methods showed good accuracy. The maximum distance error were in the range of few hundred meters.
- The impact of measurement inaccuracy, load asymmetry and fault resistance were minimal.

Impact for distribution system innovation:

- The simulation results were promising and strengthens the prospect of further testing of the methods in real networks and adoption of the methods for a real-world implementation.

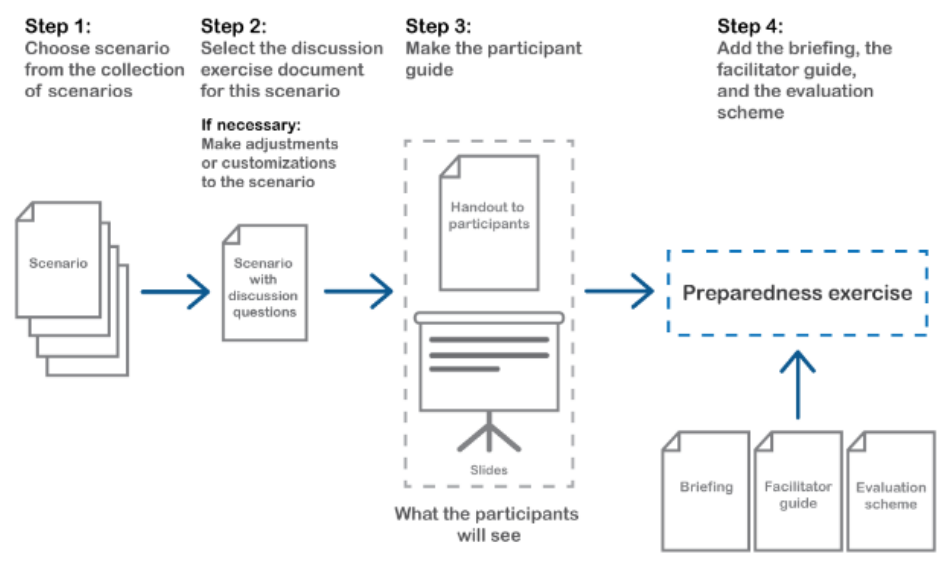
Reference in CINELDI:

- T.A. Zerihun, T. Treider, H. Taxt, L.B. Nordevall, T.S. Haugan: "Two novel current-based methods for locating earth faults in unearthed ring operating MV networks", submitted to ELSEVIER/EPSR 2021, and under review.

CINELDI result: Scenarios for collaborative preparedness exercises (WP2)

Challenge and objective:

- Many smaller DSOs rely heavily on their IT/OT vendors to handle cyber incidents
- Investigation into which factors may contribute to making it easier to include vendors in preparedness exercises.



Work performed:

- Interviews with stakeholders
- Design of incident response exercises
- Trial run of exercise with one DSO and two vendors

Significant results:

- Specific guidance on how to include vendors in exercises
- 7 reusable attack scenarios for exercises

Impact for distribution system innovation:

- DSOs can include vendors in preparedness exercises in a meaningful way.

Reference in CINELDI:

- M. Langås, S. Løfqvist, B. Katt, T. Haugan, M.G. Jaatun: With a Little Help from Your Friends: Collaboration with Vendors During Smart Grid Incident Response Exercises, 2021 European Interdisciplinary Cybersecurity Conference, Association for Computing Machinery, New York, NY, USA, 46–53.

CINELDI result: New smart grid stencils for the Microsoft Threat Modelling Tool (WP2)

Challenge and objective:

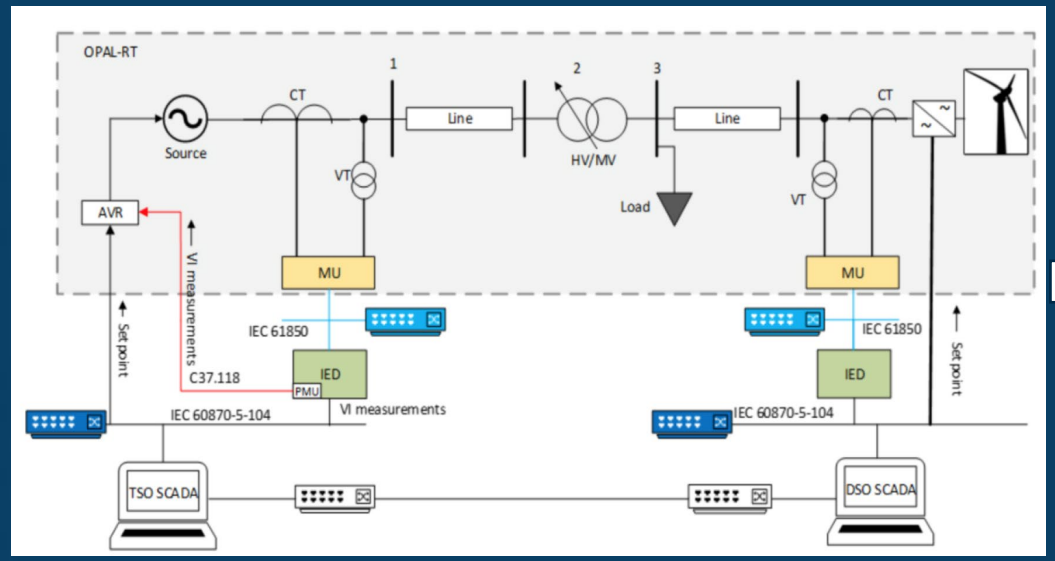
- Threat modelling is time consuming and greatly dependent on the participants
- Create a tool to ease and improve this activity

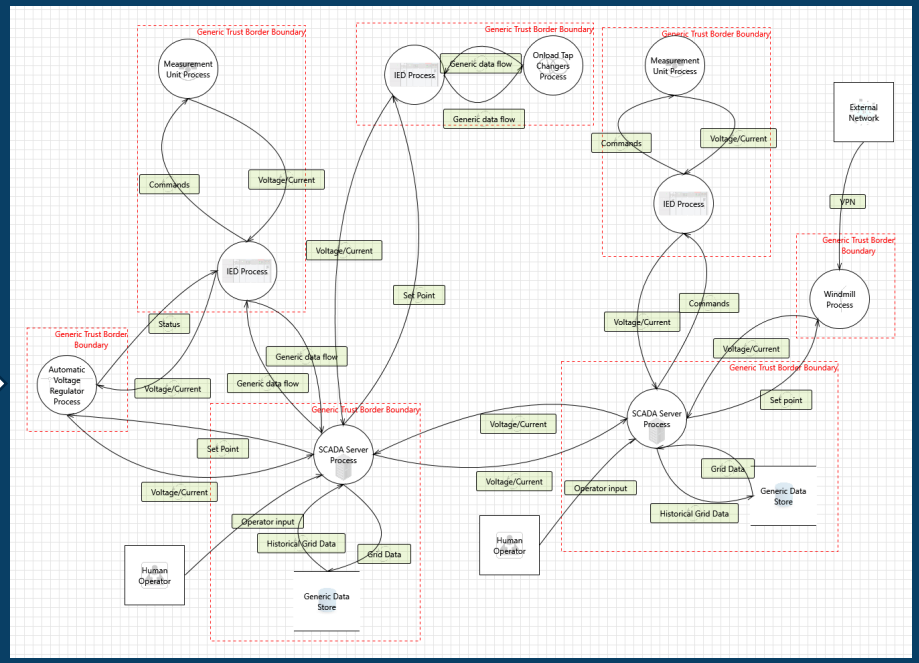
Impact for distribution system innovation:

- Enabling more efficient threat modelling process contributing to a more secure distribution grid

Work performed:

- Created a Smart Grid Template for MS Threat Modelling Tool made up of stencils and threats
- Created a model of the TSO-DSO reactive power use case, but did not perform the threat modelling





Reference in CINELDI:

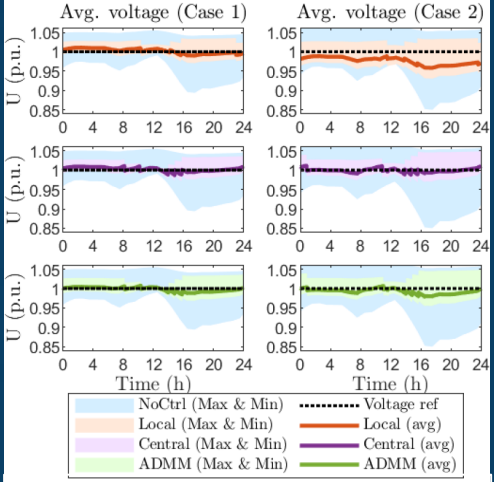
- L.H. Flå, R. Borgaonkar, I.A. Tøndel, M.G. Jaatun: Tool-assisted Threat Modeling for Smart Grid Cyber Security. 2021 International Conference on Cyber Situational Awareness, Data Analytics and Assessment (CyberSA), IEEE.

CINELDI result: Distributed ADMM* strategy for optimal control of DERs and OLTCs in a radial distribution grid (WP2)

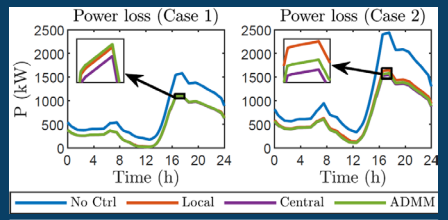
***ADMM** -alternating direction method of multipliers

Challenge and objective:

- To harness the potential from Distributed Energy Resources (DERs), appropriate control strategies and architecture are required in the distribution system to seamlessly control and cooperate the DERs with other voltage regulatory devices.



The average voltages together with their maximum and minimum voltages when using the local, centralized (central), and distributed (ADMM) control architectures. The blue area shows the maximum and minimum voltages when the network is left uncontrolled (NoCtrl), with the black dashed line being the desired voltage reference for the network.



The active power losses when using the local, centralized (central), and distributed (ADMM) control architectures.

Work performed:

- In this work, a centralized, a local, and a distributed control system have been designed with an emphasis on the distributed controllers.
- In this work, an ADMM-based distributed control strategy is developed that is able to control both continuous and binary variables in a distribution grid.

Significant results:

- The three control strategies give very similar results when **designed appropriately**, demonstrating that near-optimal control can be achieved in multiple ways.
- Other aspects such as ICT infrastructure, resilience towards cyberattacks, and scalability should probably be of bigger concern when designing control systems for power systems.

Impact for distribution system innovation:

- Reduced infrastructure investment by using flexibility resources for voltage regulation.
- Improved voltage quality and reduced losses.
- Potentially increased resilience towards mis use cases with appropriate control structure.

Reference in CINELDI:

- J.R.A. Klemets, M.Z. Degefa: "A distributed ADMM strategy for optimal control of DERs and OLTCs in a radial distribution grid", Paper is submitted to ELSEVIER journal EPSR and it is under review.

CINELDI result: Mapping of barriers and potential for flexibility (WP1/WP3)

Challenge and objective:

- Increased consumption due to electrification of transport and new loads
- Limited grid capacity
- Flexibility can be used to improve the utilization of existing grid and as an alternative to grid investments
- A more proactive grid operation is necessary, where flexibility is included

Work performed:

- 7 Norwegian DSOs have been interviewed
- Data from the interviews are analysed and described in a common report from Energi Norge and CINELDI

Significant results:

- Potentials and barriers are grouped into four C's

Impact for distribution system innovation:

- Increased utilization of flexibility in both planning and operation of the distribution grid

Four C's for potentials and barriers

Culture	Competence	Customer awareness	Communication systems
•Experience through pilot projects •Sharing of knowledge with other DSOs	•Mapping of grid problems that can be solved by flexibility, and of available flexible resources •Common rules can be basis for standardization	•How they can contribute with flexibility as a cost-efficient solutions solving grid problems	•Operation system with information about available flexibility, automation of connection/disconnection of resources •Use smart meter data for information about the load in the distribution grid

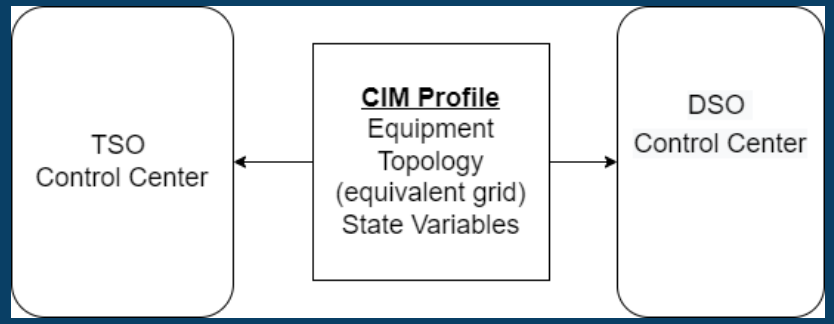
Reference in CINELDI:

- K.W. Høiem, V. Mathiesen, I.B. Sperstad, H. Sæle: "Mulighetsstudie. Bruk av fleksibilitet i nettselskap", Rapport, Energi Norge/CINELDI, 2021.

CINELDI result: TSO-DSO CIM Profile for Voltage Control (WP3/WP2)

Challenge and objective:

- Operational coordination between TSO and DSO for control of reactive power needs to be improved to handle more distributed energy resources in the distribution grid
- The appropriate information exchange methods using Common Information Model (CIM) and Inter-Control Centre Protocol (ICCP) should be identified



Work performed:

- The smartgrid lab was used to evaluate the performance impact of different levels of information exchange between TSO and DSO.

Significant results:

- It was found that (a subset of) the CGMES CIM profile was sufficient also for the TSO-DSO information exchange for the voltage control use case.

Impact for distribution system innovation:

- The CGMES profile is a good starting point for the TSO-DSO information exchange.
- For other use cases it may be needed to add some distribution system specific information to the profile

Reference in CINELDI:

- M.Z. Degefa, H. Lundkvist, S. Sanchez-Acevedo, K.N. Gregertsen: "Challenges of TSO-DSO Voltage Regulation Under Real-Time Data Exchange Paradigm". A paper is submitted and under review in IEEE Transactions on Smart Grid.

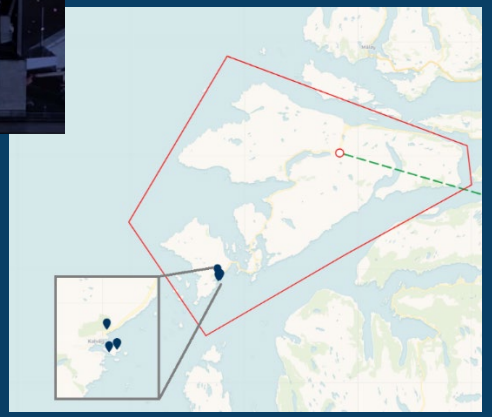
CINELDI result: Experience from Norwegian intelligent electricity distribution pilot projects (WP3/WP Pilot)

Challenge and objective:

- Involvement of industry in centre research via pilot projects

Skagerak Energilab / Lede.
Pilots: Transition to island mode and Optimization of local balancing with batteries

Haugaland Kraft Nett/Fagne.
Pilot: Flexibility market established to solve voltage problems on an island



Linja.
Pilot: Flexibility market established to solve voltage problems due to bottlenecks in the distribution grid on the mainland

Work performed:

- A common process for initiating, executing, and finalising the pilot projects is established, to ensure a predictable and open process involving all relevant parties, and ensuring that the topics treated within the different pilot projects are in line with CINELDI's goals and ambitions, and support the common target of achieving system innovation.

Significant results:

- The common process for pilot projects ensures that dissemination is carried out and that cooperation between CINELDI partners is initiated.

Impact for distribution system innovation:

- Increased knowledge related to planning, execution and finalization of pilot projects

Reference in CINELDI:

- H. Sæle, M. Istad, S.M. Oland, S.A. Kjerpeset, R. Johansen, H. Hagen, K.F. Hansen, L.E. Nesse: "Experience from Norwegian intelligent electricity distribution pilot projects", CIRED 2021.

CINELDI result: Flexibility Solutions in Distribution Networks (WP3)

Challenge and objective:

- The power system is currently facing challenges regarding increasing electrification, the integration of variable renewable energy (VRE), and the growth of distributed energy resources (DER).
- Flexibility in the power grid is seen as an important part in overcoming these challenges.

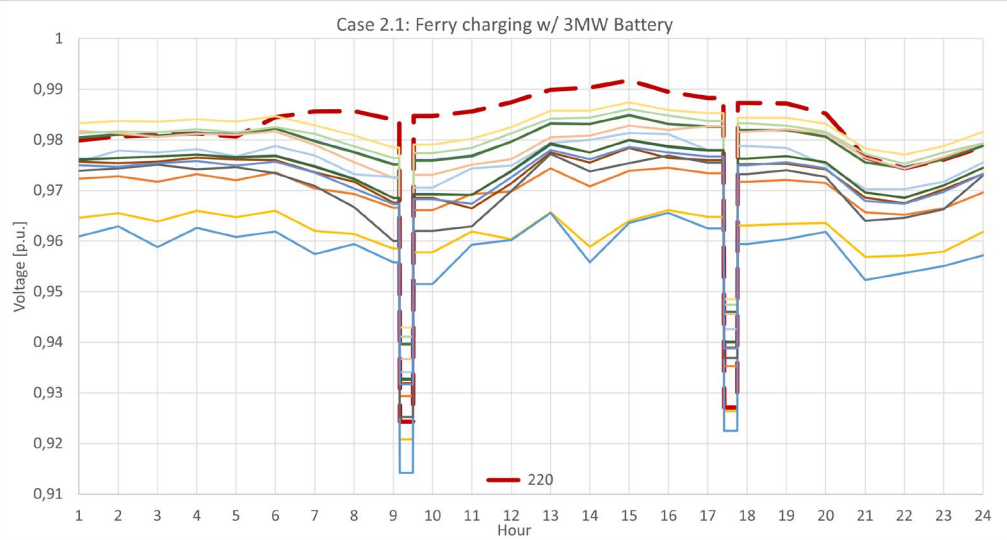


Figure: Voltage profiles of all loads, including the ferry substation

*BESS = Battery Energy Storage System

Work performed:

- Analysis of the potential and need for flexibility in the distribution grid on the island of Utsira.
- Scenarios show how increased electrification will cause significant voltage variations in the grid.
- Scenarios including flexibility solutions, demonstrate a positive impact on grid conditions.

Significant results:

- High Demand Side Response(DSR) rate for smart charging of EVs will reduce voltage variations.
- Load shifting with BESS* for charging the planned electric ferry will reduce voltage variations and reduce needed grid reinforcements.
- The load increase due to EVs will demand an increase of power supply from the VRES.
- The flexibility potential in thermal loads is not sufficient to cover predicted increase in power demand.

Impact for distribution system innovation:

- Knowledge about how flexibility can be used to cope with the expected electrification

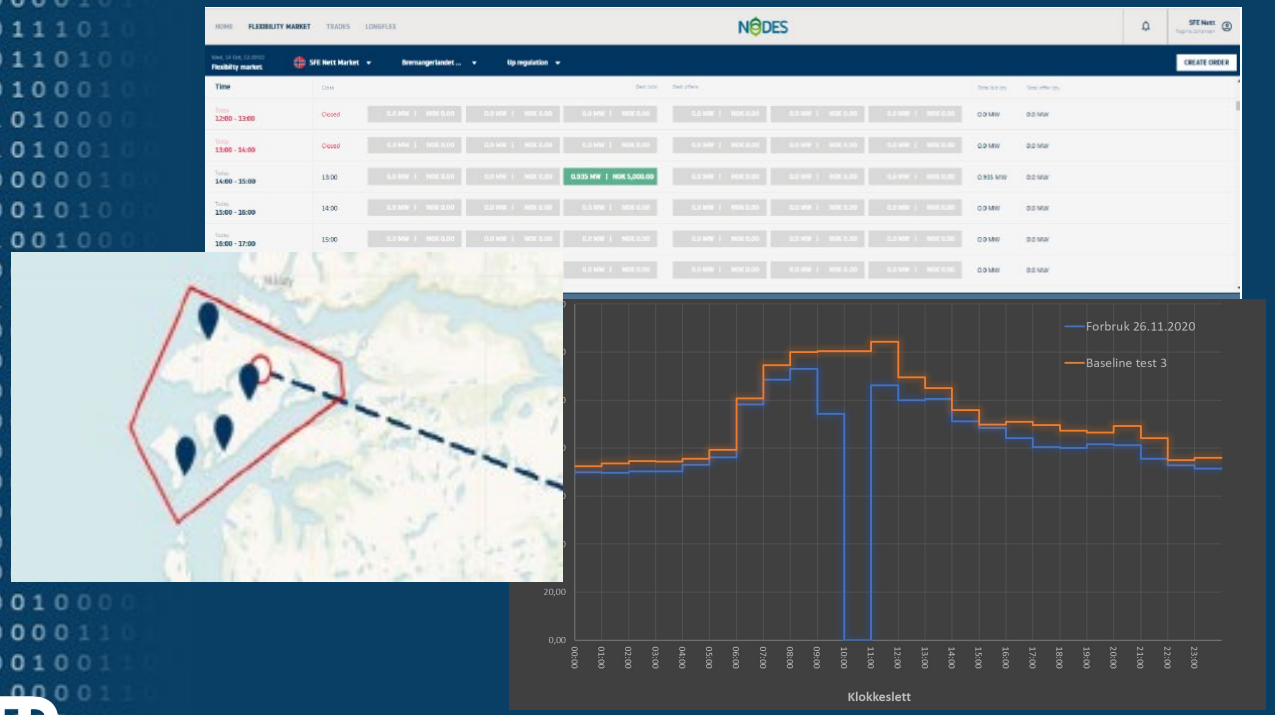
Reference in CINELDI:

- A. Grøttås, A.T. Nestås: "Flexibility Solutions in Distribution Networks. Case Study Utsira, MSc-thesis, NTNU, June 2021.

CINELDI result: Flexibility market for solving grid problems (WP3/WP Pilot)

Challenge and objective:

- Problems with under voltages in peak load periods.
- The market platform will be used to buy flexibility in these periods to reduce the load, contributing to improved voltage quality.



Work performed:

- Established a flexibility market in an area connected to the power system via a long power line.
- The geographic area of the pilot identified (red lines surround the area where there is a need to reduce the load, and the blue dots indicate the location of identified flexibility resources).
- Agreements related to bidding flexibility into the markets with industry and municipal buildings.

Significant results:

- Flexibility activated in a municipal building, where blue curve represents the actual power consumption for the municipal building, while the orange curve the estimated one (baseline). Linja purchased flexibility between 10:00-11:00.

Impact for distribution system innovation:

- Knowledge about how market-based solutions can be used to solve grid problems

Reference in CINELDI:

- SINTEF blogg "Tester handel med fleksibilitet", 15. oktober 2020.

CINELDI result: Harmonic Virtual Impedance Design for Optimal Management of Power Quality in Microgrids (WP4)

Challenge and objective:

- Power quality is an important concern for practical microgrid (MG) applications due to the widespread use of nonlinear loads
- It is characterized by the implicit trade-off between voltage quality in the MG nodes and harmonic current sharing between distributed generators (DGs)

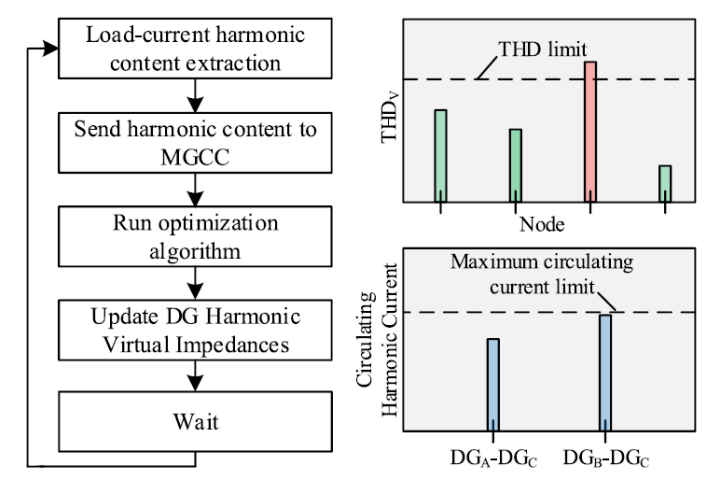


Figure: Process for voltage quality improvement

Work performed:

- Instead of using more costly alternatives as filters, this work addresses the modification of the control system of the DGs that represents a cheaper and more practical solution. Virtual impedances (VIs) can be included in the controller to improve current sharing

Significant results:

- An optimization algorithm for setting the harmonic VIs of the DGs in a multibus MG is developed where the objective is voltage quality improvement
- This optimization algorithm can be configured for any degree of harmonic current sharing between the DGs

Impact for distribution system innovation:

- Less costly alternatives will become available to maintain power quality in microgrid applications

Reference in CINELDI:

- F. Göthner, J. Roldán-Pérez, R. E. Torres-Olguin and O. -M. Midtgård, "Harmonic Virtual Impedance Design for Optimal Management of Power Quality in Microgrids," in IEEE Trans. on Power Electronics, 2021.

CINELDI result: Reduced-Order Model of Distributed Generators with Internal Loops and Virtual Impedance (WP4)

Challenge and objective:

- Reduced-order converter models are useful in microgrid applications for being less computationally expensive and simpler to analyse.
- Models already used, only include basic control loops (ignores virtual impedance and internal control loops),
- The frequency range validity of these models has neither been thoroughly studied

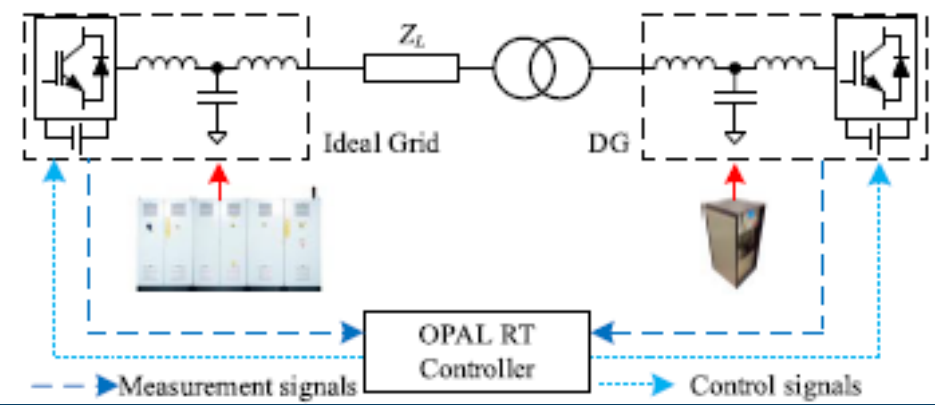


Figure: Single-line diagram for experimental setup

Work performed:

- A low-order model of a droop-controlled converter that includes internal control loops and virtual impedances is derived.
- The validity of the assumptions used to reduce the model is analysed and a criterion for deciding the frequency range in which the model can be used is proposed.

Significant results:

- The model shows that the DG internal control loops tends to reduce the stability margins.
- It is also shown that including quasi-stationary virtual impedances increases the stability margins.
- While the transient part of the virtual impedance, reduces the stability margins.

Impact for distribution system innovation:

- The inclusion of critical control designs will preserve a simple model but improve the accuracy

Reference in CINELDI:

- F. Göthner, J. Roldán-Pérez, R. E. Torres-Olguin and O.-M. Midtgård, "Reduced-Order Model of Distributed Generators With Internal Loops and Virtual Impedance, in IEEE Transactions on Smart Grid, 2022.

CINELDI result: A Robust Circuit and Controller Parameters' Identification Method of Grid-Connected Voltage-Source Converters Using Vector Fitting Algorithm (WP4)

Challenge and objective:

- In system modelling and analysis internal parameters may be missing due to intellectual property rights or parameters variation caused by operating condition change, temperature fluctuation, and aging.
- This will badly affect the accuracy unless these parameters are identified.

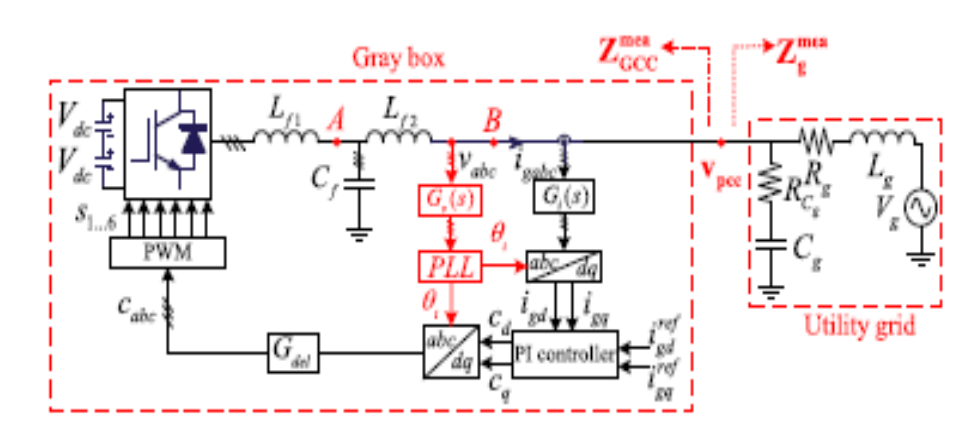


Figure: Control strategy for grid-connected VSC

Work performed:

- A vector fitting (VF) algorithm for robust parameter identification is developed to identify circuit and controller parameters of the grid-connected Voltage Source Converters based on the measured impedance frequency responses .

Significant results:

- The proposed method is able to identify the circuit and controller parameters when detailed parameters are missing
- The effectiveness of the proposed circuit and controller parameters' identification method is validated by theoretical demonstration, OPAL-RT-based real-time simulation, and experimental validation.

Impact for distribution system innovation:

- It will improve the accuracy of modelling and simulation since uncertain or unknown parameters have less impact on the results

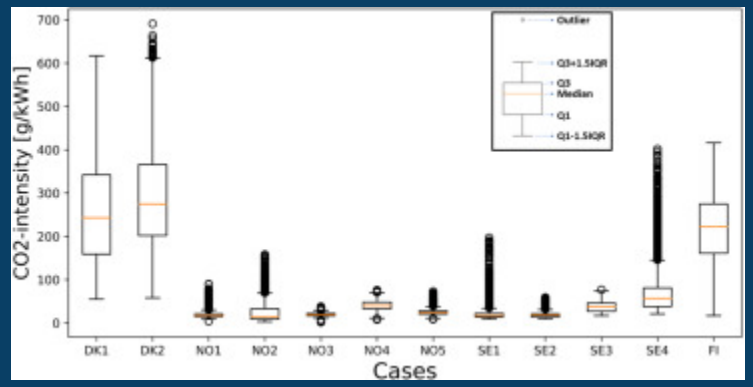
Reference in CINELDI:

- W. Zhou, R. Torres-Olguin, F. G□othner, J. Beerten, M. K. Zadeh, Y. Wang and Z. Chen "A Robust Circuit and Controller Parameters Identication Method of Grid-Connected Voltage Source Converters Using Vector Fitting Algorithm," in IEEE Journal of Emerging and Selected Topics in Power Electronics, 2021.

CINELDI result: Operation model for ZEB with emission compensation (WP5)

Challenge and objective:

- The primary objective of Zero Emission Buildings (ZEBs) is to achieve net zero emission over the buildings' lifetime.
- To achieve this goal, accurate cost-effective emission compensation is needed during the operational phase.
- We aim to capture the long-term economic impact of emission compensation for a ZEB during operation.



Overview of hourly -intensities for the Nordic bidding zones in 2017.

Work performed:

- Operational strategy for a building with emission compensation.
- Using Stochastic Dynamic Programming for energy storage optimization.
- Compare the operational strategy for a Norwegian and Danish case.

Significant results:

- Emission compensation has a significant impact on the local energy system operation.
- Penalty cost of 10 EUR/kg results in zero net emission. Total cost increased by 5 %.

Impact for distribution system innovation:

- Give indication of value of flexibility from end-users with local emission targets.

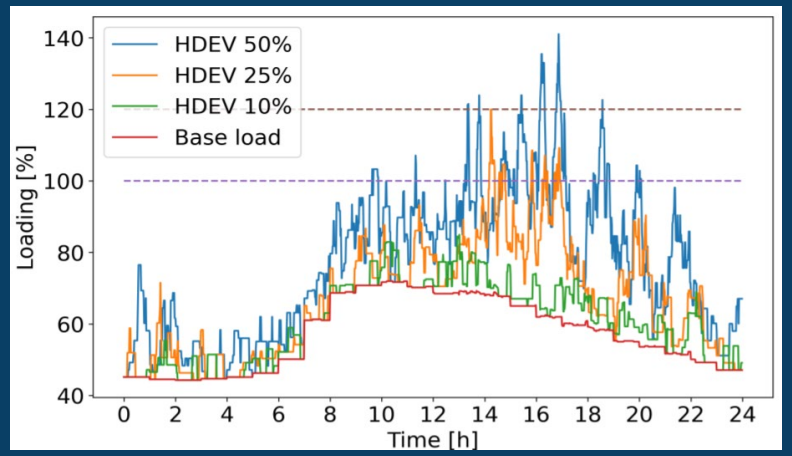
Reference in CINELDI:

- K.E. Thorvaldsen, M. Korpås, K.B. Lindberg, H. Farahmand: "A stochastic operational planning model for a zero emission building with emission compensation", Applied Energy 302, 117415, 2021.

CINELDI result: Charging profiles for Heavy Duty Electric Vehicles (WP5/ FuChar)

Challenge and objective:

- The upcoming heavy-duty electric vehicles (HDEVs) are expected to have a charging power between 100-1600 kW
- A transition to HDEVs can cause challenges to the power grid.
- We aim to create load profiles of a high-power charging station for HDEVs in power flow analysis



Transformer loading in a Norwegian transit area with increasing share of heavy duty electric vechicles

Work performed:

- Developed load model for HDEVs
- Constructed a case study for a relevant Norwegian areas
- Evaluated impacts on increasing mandatory breaks for HDEV drivers

Significant results:

- HDEV charging causes overloading issues when share of EVs is in the range 25-50 %
- Increasing mandatory breaks for HDEV drivers reduces charging peaks significantly

Impact for distribution system innovation:

- Crucial to understand the grid impact of new types of EVs with very with power demands

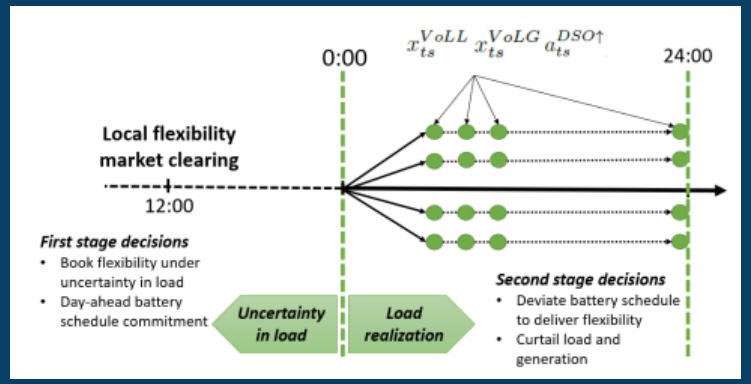
Reference in CINELDI:

- K.K. Fjær, V. Lakshmanan, B.N. Torsæter, M. Korpås: "Heavy-duty electric vehicle charging profile generation method for grid impact analysis", SEST 2021.

CINELDI result: Stochastic Model for flexibility procurement and activation by DSOs (WP5/ DigEco)

Challenge and objective:

- Recently, Distribution System Operators (DSO) are facing increasing congestion management challenges in their grids
- DSOs are in many countries not allowed to buy or sell electricity, but must request flexibility through a future local flexibility market (LFM)
- This paper proposes a LFM architecture which allows the DSO to book flexibility from aggregators and activate flexibility when needed



DSO flexibility booking (1.stage) and activation (2.stage) problem

Work performed:

- Developed a stochastic optimization program where the DSO books and activates flexibility considering the cost of energy not served and cost of battery degradation
- Analysed th use of the model for a Norwegian case study
- Studied the impact of battery costs and Value of Lost Load (VoLL) pricing

Significant results:

- Results illustrate that the batteries are nowadays at affordable prices for flexibility provision
- Affordable battery price where no curtailment occurs, is only achievable when prices reach below 200 €/kWh, depending on VoLL

Impact for distribution system innovation:

- This is a decision aid model and flexibility market architecture that can be deployed for handling local grid congestions

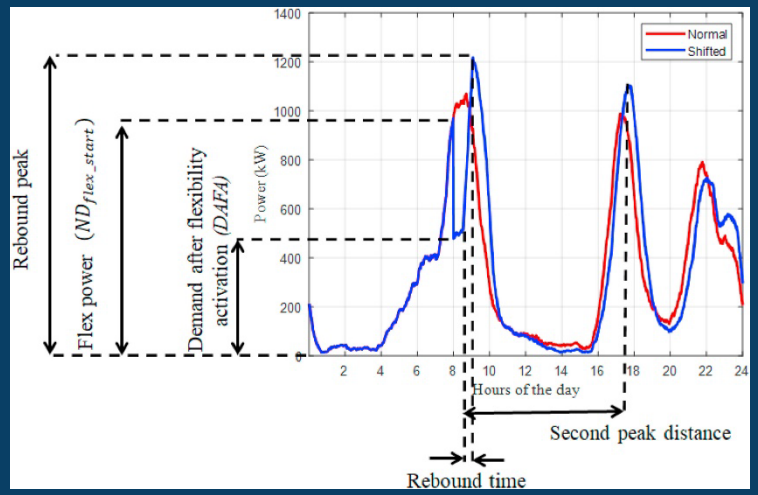
Reference in CINELDI:

- S. Bjarghov, M. Kalantar-Neyestanaki, R. Charkaoui, H. Farahmand: "Battery Degradation-Aware Congestion Management in Local Flexibility Markets", IEEE PowerTech 2021.

CINELDI result: Quantification of electric water heater flexibility potential in Norway (WP5)

Challenge and objective:

- Simultaneous activation of flexibility from thermal loads can cause adverse rebounds later.
- DSO must be aware of such impacts.
- This work propose parameters for flexibility activation from electric water heaters (EWHs) are proposed and flexibility potentials are computed for Norway.



EWH rebound characteristics

Work performed:

- Maximum flexibility activation time calculation method is suggested.
- Uncoordinated flexibility activation impact is characterized.
- Simple rebound reduction technique is proposed and compared with blind activation.

Significant results:

- Highest average flexible power potential is 54% at 8:00 a.m. for a duration of 1 h.
- EWHs can serve as FCR at peak hours with high ramp-up and ramp-down rates of 48.5% and 23.8% per minute and as FRR during non-peak hours.

Impact for distribution system innovation:

- DSO must have an overview of the impact of flexibility activation on the demand side.

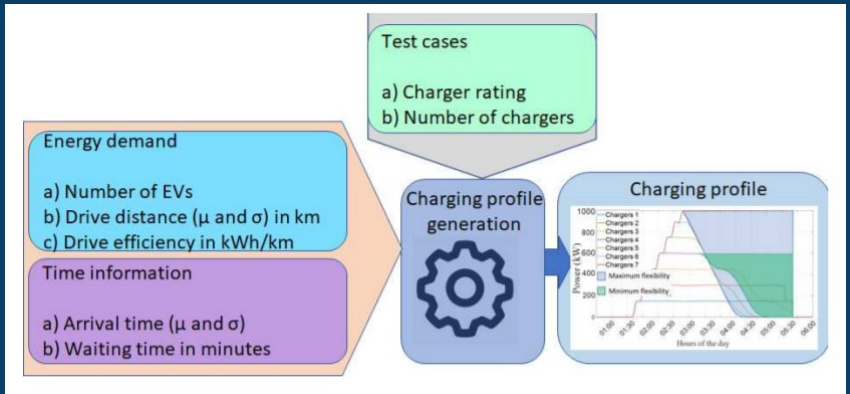
Reference in CINELDI:

- V. Lakshmanan, H. Sæle and M.Z. Degefa: "Electric water heater flexibility potential and activation impact in system operator perspective–Norwegian scenario case study", Energy, vol 236, 2021.

CINELDI result: EV fleet charging profile tool for grid planning (WP5/ FuChar)

Challenge and objective:

- Electrification of bus fleets presents challenges to DSOs regarding peak demand and utilization of grid infrastructure.
- The work presents a generic mathematical formulation for a tool to generate the charging profile from EV fleet operators to be used in grid planning and flexibility assessment.



Information flow diagram for charging profile creation.

Work performed:

- Developed tool to be used by DSOs for generating charging profiles for electric bus fleets.
- Developed a method to identify the region of flexibility that fleet operators can offer to DSOs.
- Developed method for calculating the simultaneity factor for fleet charging.

Significant results:

- The tool has been tested on scenarios for Trondheim.
- Peak fleet demand varies from 300 kW to 1050 kW.
- Bus fleets can provide flexibility between 40 % and 230 % of their daily energy demand.

Impact for distribution system innovation:

- High-resolution EV charging profiles provides better knowledge about peak demand and demand variation, which helps DSOs to plan grid infrastructure rationally.

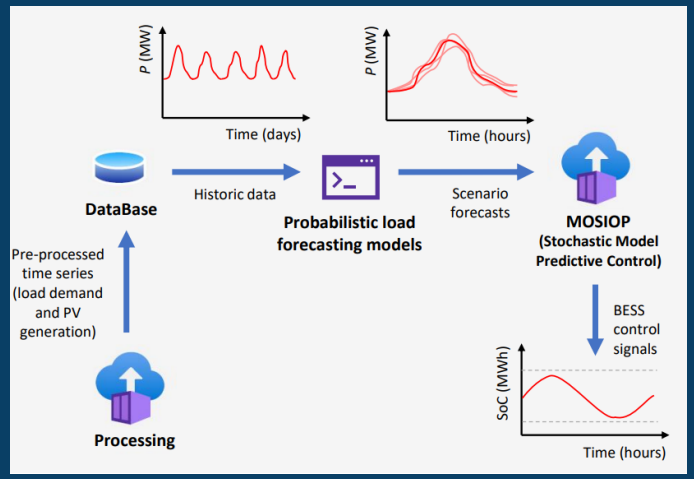
Reference in CINELDI:

- V. Lakshmanan, B.N. Torsæter, H. Sæle, O.A. Hjelkrem: "Charging Profile Generation Tool for Grid Planning and Flexibility Assessment of EV Fleets, SEST 2021.

CINELDI result: A framework for remote Energy Management System (EMS) development using MPC (WP5)

Challenge and objective:

- Energy Management Systems (EMSs) are software tools that support the grid operators to monitor, control and optimize power system assets.
- Deployment of an EMS on a real system is time-consuming and may be hard to implement.
- This work draws inspiration from the Software as a Service (SaaS) business model to propose an EMS^{2}aaS framework.



Data flow and interfaces in the EMS framework

Work performed:

- Created an EMS^{2}aaS framework for researchers and developers consisting of i) Cloud-based EMS that scales for microgrid HWIL, ii) Probabilistic load forecast model, iii) Stochastic MPC
- The software framework is based on the "Docker" technology (www.docker.com)

Significant results:

- The tool has been tested on a computer model of the Skagerak Energilab microgrid
- The stochastic MPC reduced the operational cost by 26 % for the test case.

Impact for distribution system innovation:

- EMS development based on SaaS can ease the implementation, testing and verification of advanced control strategies for microgrids

Reference in CINELDI:

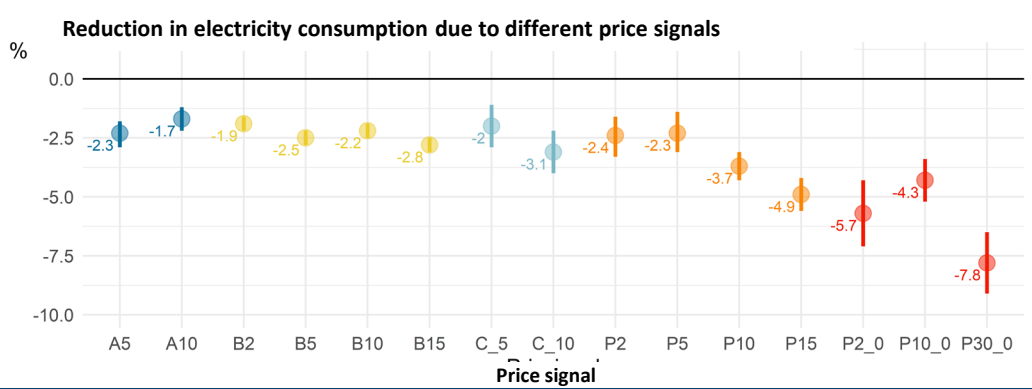
- G. Marafioti, S. Fossøy, J.P. Maree, I.B. Sperstad: "A EMS^{2}aaS: A Dockerized framework for remote EMS deployment, SEST 2021.
- J.P. Maree, S. Gros, V. Lakshmanan: "Low-complexity Risk-averse MPC for EMS", SmartGridComm 2021.

CINELDI result: iFleks – Future price elasticity in electricity consumption (WP5)

Challenge and objective:

- To understand how variable energy prices in the future will affect the electricity consumption in peak load periods when stronger price signals are expected and more technology solutions are available.

Results from the winter 2021



Work performed:

- Price experiments and questionnaires among 4375 households and some office and public buildings during the winter 2020 and 2021.
- Smart meter data are analysed to study the connection between price and demand.

Significant results:

- 2-11% reduction in electricity consumption in peak price hours based on manual measures.
- Approx. 50% of the households responded to price signals.

Impact for distribution system innovation:

- Improved understanding of demand response and the strength needed in price signals to achieve a reduction in peak load sufficient enough to postpone grid investments.

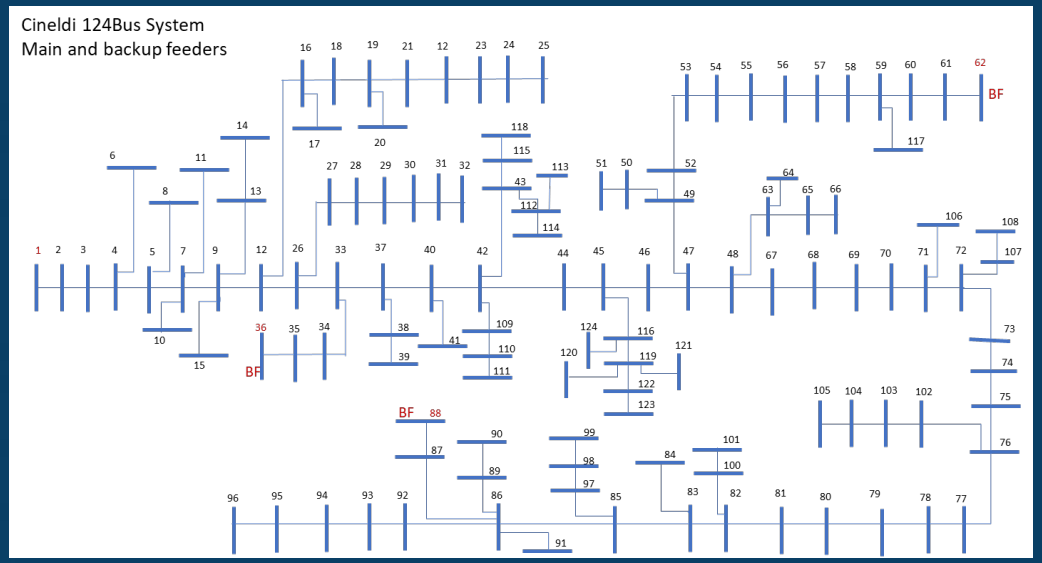
Reference in CINELDI:

- T. Siebenbrunner, M. Hofmann: "Framtidig prisfølsomhet til sluttbrukere. Sluttrapport iFleks", Statnett 2022.
- iFleks – Prisfølsomhet, Statnett web.

CINELDI result: Reference grid data set (WP6)

Challenge and objective:

- International test grid data sets are typically made for academic purposes, for verification and validation of new methods, and based on international data. Such data sets are often not suitable for studying realistic problems. Thus, it is important to establish reference grid data sets representative for Norwegian distribution grids.



Work performed:

- Grid data from a real MV distribution grid are anonymised and adapted to establish reference grid data representative for Norwegian distribution grids.
- The basic data set is further built on to provide data set relevant for a case study on flexibility

Significant results:

- A basic MW distribution grid data set is established based on a real anonymised Norwegian MV grid.
- The basic data provides data sets relevant for Smart Grid research and may be further built on for case studies on flexibility, security of electricity supply etc.

Impact for distribution system innovation:

- The reference data makes it possible to analyse different technologies, scenarios and challenges in more realistic environments. It enables fundamental analyses and allows for studying problems to be addressed for the future system.

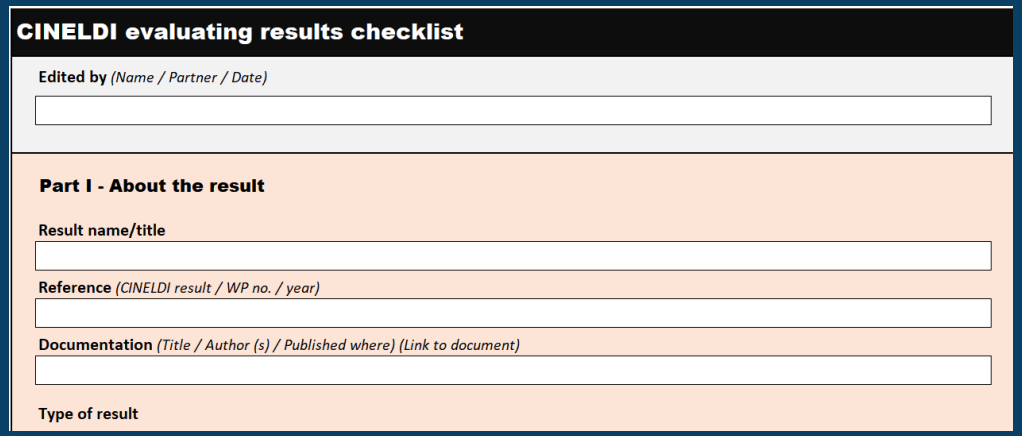
Reference in CINELDI:

- O.B. Fosso, G. Kjølle: "Norsk referansenett for forskning på smarte strømnett", #SINTEFblogg.

CINELDI result: Checklist for evaluation of results from research and pilot projects (WP6)

Challenge and objective:

- Long term knowledge building research is mostly conducted on lower TRL while pilot projects typically raise the results a bit higher on the TRL scale. However, to develop research into innovation requires efforts in various directions to implement and start using the results. Examples: establish and make available relevant data and tools, change work processes, competence building, implementing new technologies, regulatory change, etc.



CINELDI evaluating results checklist

Edited by *(Name / Partner / Date)*

Part I - About the result

Result name/title

Reference *(CINELDI result / WP no. / year)*

Documentation *(Title / Author (s) / Published where) (Link to document)*

Type of result

Work performed:

- A check list is developed to assist in evaluating research results and pilot projects results to identify needs for and barriers towards start implementing results and make innovations.

Significant results:

- The checklist consists of four parts:
- 1) About the result, target groups, benefits, contributions to sustainability, etc.,
- 2) What is needed to have in place to start using the result ,
- 3) Barriers and barrier-reducing measures,
- 4) Further research and spin-off possibilities.

Impact for distribution system innovation:

- The checklist facilitates the process of implementing results, such as reducing barriers, acceptance of changing work processes, culture, achieve leadership support.

Reference in CINELDI:

- The checklist is implemented in an Excel sheet and made available on the CINELDI web (Norwegian and English version).