Norwegian Centre for
Environment-friendly
Energy Research

CINELDI

Centre for intelligent electricity distribution

Annual report 2022

How can we make our electricity grid more efficient, flexible, and resilient?

These are the challenges we are solving at CINELDI.

Our society is becoming increasingly electrified. That means we need to generate more renewable electric power – which needs to be transported from the producer to the consumer. Our electricity grid is the backbone of the power system and has to be stable enough and properly sized. Sustainability targets cannot be met unless the distribution system undergoes this necessary transformation.

CINELDI's main objective is to develop new concepts, technologies and solutions that will enable the cost-effective realisation of a flexible and robust electricity distribution system. These innovations will contribute to a more sustainable energy system by increasing the use of renewable energy sources and facilitating a more efficient power and energy use.

Following the rollout of the Advanced Metering Infrastructure in 2019, CINELDI began researching new technologies for the digitalisation of the electricity grid. Research activities place a particular emphasis on new and emerging topics like security of supply, cyber security, microgrids and flexibility resources.

CINELDI's research comprises the fields of electric power engineering, cybernetics, information technology and communication technology. It also incorporates social sciences to understand the real-life applications of these technologies.

The R&D results will be integrated into stakeholder guidelines and recommendations for a holistic transition to a smarter and more flexible distribution system in Norway. Our innovations aim to considerably reduce total distribution system costs, and leverage business opportunities for technology providers in both national and international markets. CINELDI also focuses on increasing the knowledge, strengthening education, and establishing international collaboration within our fields of research.

Contents

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Security of supply, geopolitics, and other driving forces

Driving forces and scenarios for the future intelligent electricity grid were described during the centre's three first years. In 2022, we finished our updates on these driving forces and mini scenarios, in line with societal developments.

Electrification had already emerged as a strong driver for the electricity grid due to the accelerated **climate change crisis**, and the need for measures to **utilise existing grids** became more pressing. As a result of the energy crisis in Europe, the electricity price crisis in Norway, and the war in Ukraine, **geopolitics** was identified as a new megatrend that has also had an impact on the electricity grid.

Furthermore, both electrification and geopolitical tensions led to an increased emphasis on the **security of supply** for electrical power, and the electricity grid is central to this.

The purpose of identifying driving forces and scenarios is to increase the understanding of the requirements of the future electricity grid, as well as to develop good strategies for transitioning to a cost-efficient, flexible, intelligent and robust grid.

From the discussions about driving forces and megatrends and the energy situation in Europe at the board's strategy meeting in May, we concluded that CINELDI has increased its relevance as a research centre. There is an increased need to develop solutions for the future electricity grids – solutions that can handle the electrification of society and ensure the security of supply. Activities that take care of these aspects have been further emphasised and prioritised in the work plans for 2023.

Another question that needs to be addressed is how all the new renewable power production in the power system, such as small and large solar cell plants, run-of-river power plants, wind farms, etc. can be integrated into the grid. CINELDI contributes to increasing the integration of this new renewable and distributed power generation in the power grid. We also work to improve power and energy efficiency, and transport electrification.

The relevance and need for the research and piloting activities in CINELDI was further reinforced by *RePowerEU: affordable, secure and sustainable energy for Europe*, which is the EU's plan to accelerate Europe's green transition and make Europe independent from fossil energy from Russia. This means increased renewable power production, increased power and energy efficiency, and increased electrification.

Spreading the knowledge

The energy crisis in Europe and the electricity price crisis in Norway was also the theme of a series of workshops in the spring of 2022. This was a collaboration between several FMEs (CINELDI, NTRANS, ZEN, HighEFF, Include and HydroCEN), The Norwegian Academy of Science and Letters (DNVA) and Norwegian Academy of Technological Sciences (NTVA). The purpose of the workshop series was to contribute facts and knowledge to the public debate. A total of seven workshops were held on various topics, such as energy production and consumption, fair distribution and market design, carbon pricing, energy efficiency, and security of supply.

Gerd Kjølle

Dr. Gerd H. Kjølle is the CINELDI centre director and a chief scientist at SINTEF Energy Research.

She holds a PhD in Electric Power Engineering from NTNU and has more than 30 years of R&D experience from the electric power sector. Her main fields of expertise are power system reliability and security of supply.

Her work has resulted in solutions for grid operators and energy regulators, foundational information for handbooks, decision support tools, guidelines of good practice, as well as standards and regulations of grid companies. She has also contributed to educating and recruiting numerous candidates to the electric power sector.

We believe that collaboration between actors with different perspectives is the key to achieving an electricity grid that is flexible, intelligent, robust and cost-efficient. The landscape we are operating in is getting more complex, and that's why we need to work together and share new knowledge.

In 2023, we will present an open-access knowledge base that gathers all the new knowledge from CINELDI in one place. This year, we will also work on a transition strategy that explains how we can turn scientific results into the goal of a sustainable power grid for the future.

> Driving forces include megatrends, external and grid-related drivers, enablers and barriers to the development of the future electricity grid.

Sigurd Kvistad

Sigurd Kvistad is the chair of the CINELDI board, and head of the Operational Control department at Elvia.

With more than 30 years of experience in the electricity grid sector, he has been responsible for contractor operations, development projects, grid planning and grid operation.

As the project owner of several ongoing projects at Elvia, Kvistad has taken part in many R&D projects within Smart Grids throughout his career. Kvistad also takes part in different forums in the electricity grid sector related to the future grid as well as regulation of the grid companies.

Photo: Tord F. Paulsen

Highlights in 2022

Our first open «CINELDI day» was held in November, with participants from both inside and outside the consortium. This is a way to make our results available also for those outside our Consortium.

More about meeting points on page 13

We started an international webinar series with CINELDI's research combined with an international perspective. This is to reach out to the international research community within our field.

More about international cooperation on page 52

Four of our PhD's defended their thesis in 2022, and we see that they move on to relevant jobs in academia, power grid companies and the consulting industry.

More about recruitment on page 54

We had a lot of new research results and activities in 2022. For instance, we started the data acquisition for our large-scale pilot on flexibility. In this pilot project several grid companies, Statnett, Heimdall Power and researchers work together to find out how large scale instrumentation (digitalisation) of the high voltage distribution grid can contribute to realize more flexibility in the power system and what values this can create for the DSOs and TSO.

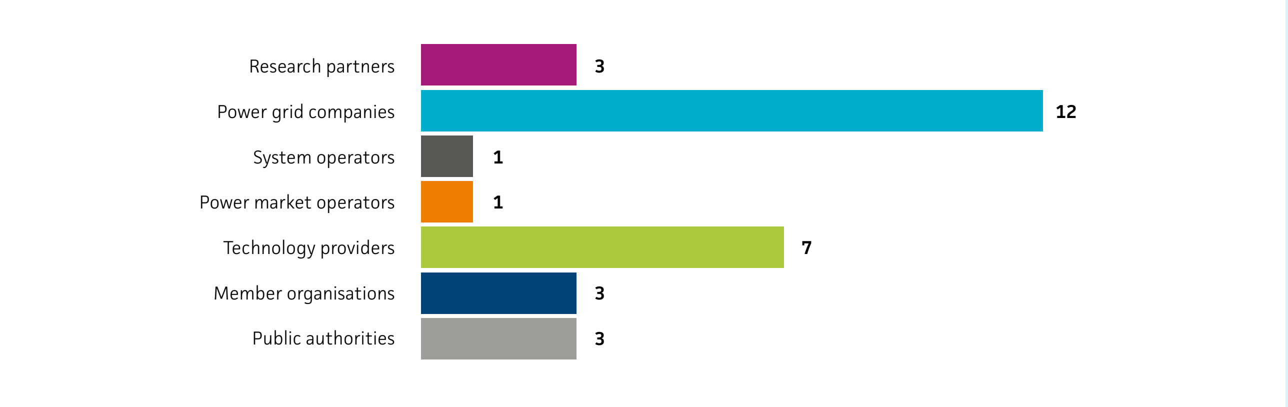
More about our research from page 21

By numbers

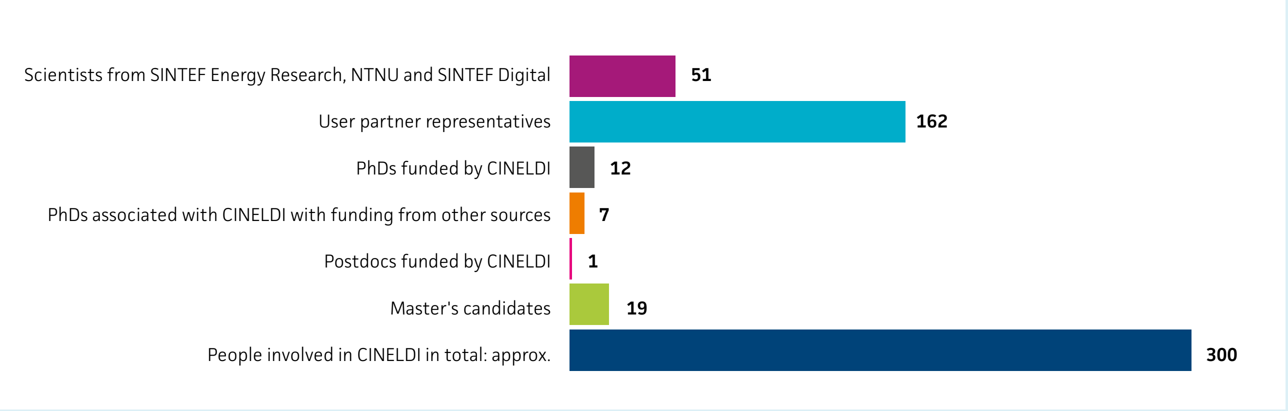
30
partners

369
MNOK

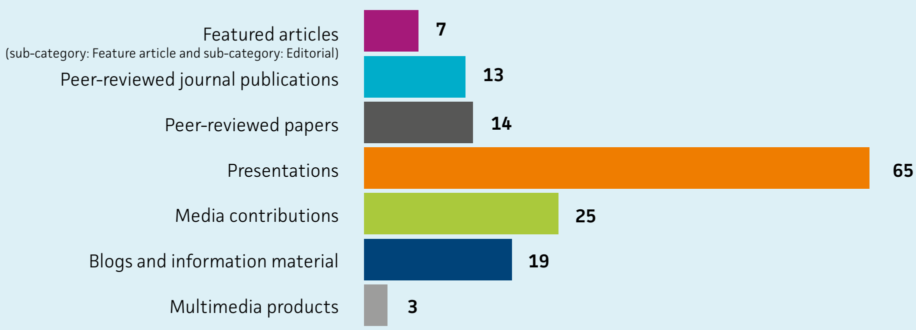
Partners



People 2022



Communication and dissemination 2022

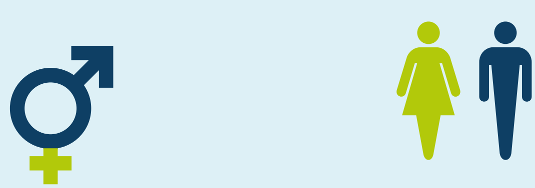


Gender balance

Executive board:
67% men, 33% women

PhD/Postdoc:
53% men, 47% women

Master's students:
63% men, 37% women



Scientists:
74% men, 26% women

Centre management:
50% men, 50% women

Vision, mission and goals

VISION

CINELDI develops the electricity grid of the future.

MISSION

CINELDI works towards digitalising and modernising the electricity distribution grid to ensure higher efficiency, flexibility, and resilience.

GOAL

CINELDI enables and facilitates a cost-efficient realisation of the future flexible and robust electricity distribution grid.

Robust grid: a grid that safeguards the security of electricity supply (energy availability, power capacity, reliability of supply and voltage quality) as well as safety, privacy and cyber security.

Realising the mission

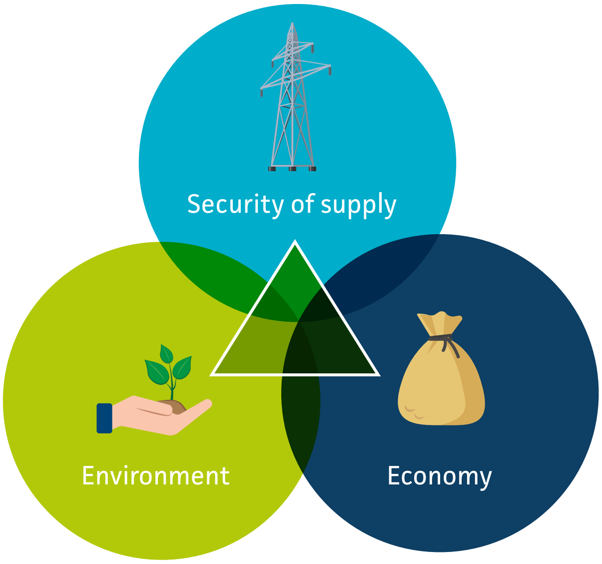
By acting as a national hub for long-term research and innovation within the field of intelligent electricity distribution, we bring together innovative stakeholders with the common task of developing and implementing new technologies, work processes and solutions. The end goal is to develop the electricity grid of the future.

In CINELDI, we are equipped to tackle this challenge with our unique combination of academic resources, computer modelling, and simulation facilities. Through the National Smart Grid Laboratory infrastructure, as well as pilots and demos, we integrate involvement from industry partners, using the physical grid owned by the distribution system operators (DSOs) and transmission system operators (TSOs) as living labs.

Reaching the goals: The energy trilemma

One of the main reasons for transforming today's ageing and passive electricity grid into an active, flexible, robust and intelligent grid – a Smart Grid – is to lay the foundation for reaching national and international energy and climate goals.

However, creating the Smart Grid is not the main challenge. The main challenge is to do it in an affordable way, while showing consideration for the environment and ensuring a high security of supply. We call this the energy trilemma.



Economy

With our research and innovation, we shall enable a cost-efficient realisation of the future flexible and robust electricity distribution grid, while minimizing strain on society. This will in turn reduce the total distribution system costs compared to the "business as usual"- solutions, by reducing both operational (OPEX) and investment costs (CAPEX).

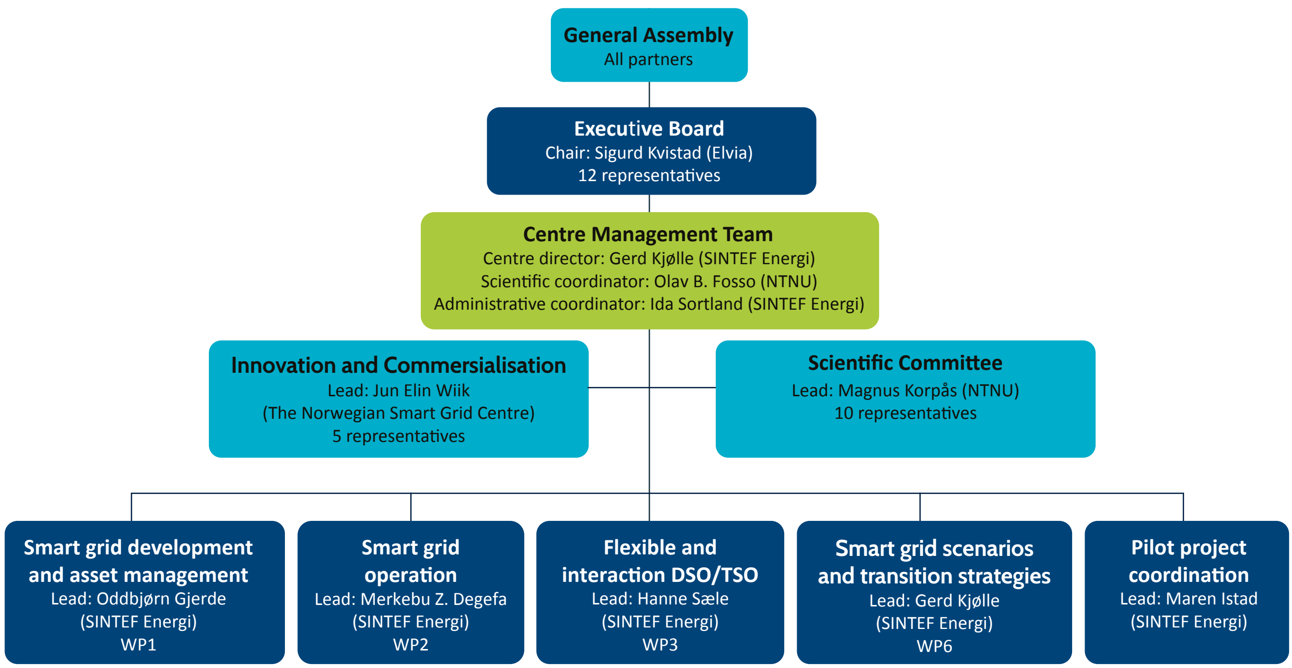
Environment

Our work paves the way for increased distributed generation from renewable energy sources, further electrification of transport, and a more efficient use of electric power and energy.

Security of electricity supply

We develop the knowledge and methods needed to ensure the security of electricity supply. We do this by focusing on energy availability, power capacity, reliability of supply and voltage quality – as well as cybersecurity, safety and privacy – as important aspects of developing the electricity grid of the future.

Organisation



Scientific Committee (SC)

The Scientific Committee (SC) is a platform for dialogue between CINELDI and key international partners. The SC discusses matters regarding the Centre's direction, lab activities, scientific ambition, and international relevance of research. The WP leaders and Centre Management participate in all SC meetings to ensure close contact between the researchers and international advisors.

In 2022, the SC held a digital meeting where the status and plans for CINELDI's work packages were presented and discussed. The SC also discussed the development of the international webinar series and which topics it should cover. Several of the experts of the SC have been directly involved in the series, as facilitators or presenters in the international webinars. After the success of cooperating on the international webinar series, we are looking forward to a planned physical workshop including PhDs and postdocs in June 2023.

The purpose of the SC is to:

- Provide advice on the research being carried out at CINELDI, as well as emerging research topics, and input to plans,
- Contribute to coordinate research and laboratory activities between participating institutions,
- Identify new areas of collaboration and contribute to organising and coordinating international research proposals.

Members of the SC:

- Professor Magnus Korpås, the Norwegian University of Science and Technology (NTNU), Norway (Leader)
- Reader Ivana Kockar, University of Strathclyde, UK
- Associate professor Mattia Marinelli, the Technical University of Denmark (DTU), Denmark
- Professor Fabrizio Pilo, the University of Cagliari, Italy
- Director Angel Diaz, Tecnalia, Spain
- Professor Bruce Mork, Michigan Technological University, USA
- Research Professor Kari Mäki, VTT Technical Research Centre of Finland, Finland
- Professor Anne Remke, the University of Münster, Germany
- Professor Madeleine Gibescu, Utrecht University, The Netherlands
- Scientist Marialaura di Somma, ENEA, Italy

Several SC members are involved in international research related to CINELDI.

Meeting points and knowledge sharing

In 2022, we entered a new stage in the Centre's dissemination of results, going from most events being open only to partners to reaching out to a broader audience in our sector, both internationally and nationally.

An international webinar series was started in September 2022 when we had to cancel the planned annual international conference for the third consecutive year due to pandemic-related travel restrictions. Read more about the international webinar series on page 52.

In place of the cancelled conference as a physical meeting point, we changed the format to CINELDI workshops, planned yearly for 2022-2024. In 2022, this was an internal consortium event in April.

In November, we hosted our "CINELDI days" – an annual two-day meeting. For the first time, day one was open for everyone interested in our field. With over

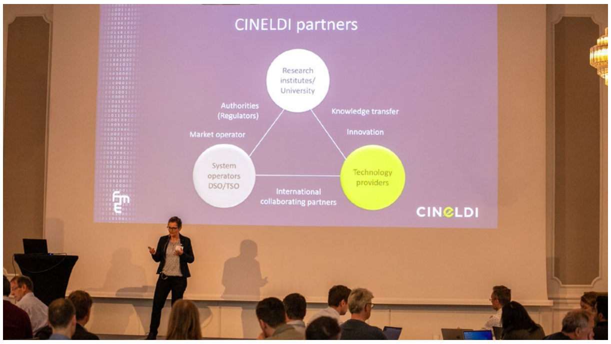
90 participants from both partner organisations and outside the Consortium, we had an inspiring day about the electricity grid of the future with presentations covering operation, planning and maintenance of the grid; technology required flexibility; and transition strategies for how to use scientific results to reach the goal of a sustainable grid for the future.

Feedback from participants outside the Consortium was good and they pointed out that sharing knowledge this way is important for the industry and is at the core of developing the electricity grid for the future.

"You never know what will come out of participating in the CINELDI days, but then you meet someone, have a chat and suddenly discover new connections and people you didn't know about"

– quote from a participant.

Throughout the year, we held six webinars for the Consortium, where we presented our latest research progress. CINELDI WP leaders, scientists, PhD candidates and partners held presentations during these webinars. We also hosted other meeting points, like online meetings, workshops, and seminars, throughout the year.



Research partners

SINTEF Energy Research

Norwegian University of Science and Technology (NTNU)

SINTEF Digital

Power Grid Companies

Agder Energi Nett

BKK Nett

Elvia

Fagne AS

Linea

Elinett AS

Linja AS

Lnett AS

Arva AS

Norgesnett

Lede AS

Tensio TN AS

System Operators

Statnett

Power Market Operators

Nodes

Technology Providers

ABB AS

Aidon

Disruptive Technologies

Embriq

Smartgrid Services Cluster

Prediktor

Heimdall Power AS

Member Organizations

Fornybar Norge

KraftCERT

The Norwegian Smart Grid Centre

Public Authorities

Directorate for Civil Protection and Emergency Planning (DSB)

The Norwegian Water Resources and Energy Directorate (NVE)

Norwegian Communications Authority

Partners and their impact

Building the smart, flexible, robust grid of tomorrow in a cost-effective way requires a huge effort from all aspects of the industry: from authorities setting the industry's framework conditions, to DSOs and TSOs operating the grid within that framework, and everyone in between. In CINELDI, we are proud to have active partners, putting in hard work and dedication towards our joint goals.

Having partners representing all areas of the industry gives us a strong platform to develop the future grid.

The twelve DSO partners of CINELDI cover about two thirds of the total Norwegian end users. The national knowledge building by this range of companies has the potential to significantly impact the power sector. Furthermore, if most of these partners utilise CINELDI's results to establish a more cost-efficient and flexible grid, they can impact society at large.

However, to truly realise our vision, more areas than those covered by our research need to be developed, such as regulation of the DSOs and the TSOs. For this reason, it is valuable that the public authorities DSB, NVE and the Norwegian Communications Authority remain partners in CINELDI.

Cooperation between partners

One of the keys to success at CINELDI is partner cooperation and knowledge sharing. We get a boost for the whole power industry and the grid when partners from technology providers, power grid companies, system operators, member organisations and research partners with different angles of incidence work together to find new solutions.

In our latest pilot, "Flexible power grid by dynamic operation", the technology provider Heimdall Power works together with three DSOs and one TSO on how digitalisation of the distribution grid can contribute to realise more flexibility in the power system and create value for both DSOs and TSO.

Pilot projects represent an area for cooperation between the different R&D partners and user partners. Thanks to our multidisciplinary research platform (which you can read more about on page 18), the R&D partners cooperate closely in all work packages (WPs). The partners are tightly integrated in CINELDI's work process. For example, representatives from the whole centre are involved in idea generation, activity selection, planning and reviews. Partners are involved through discussion of new ideas at workshops, as well as dedicated expert groups within each WP. The WPs actively use the expert groups every year when they develop their work plans.

Cooperation with other FMEs

CINELDI is one of 14 centres for Environment-friendly Energy Research (FME). These are natural collaboration partners for areas of our research that is linked to other parts of the energy system, other energy carriers, local energy communities and utilisation of flexibility and the new situation in focus in 2022: the energy crisis in Europe. This was the topic of a workshop series CINELDI organised in collaboration with several of the FMEs, The Norwegian Academy of Science and Letters (DNVA) and Norwegian Academy of Technological Sciences (NTVA).

We collaborate with FME HighEFF and FME ZEN regarding flexibility in industrial processes, buildings


Photo: Arva

and local communities respectively. Among other things, this includes the collaboration project ChiNoZEN, under the China-Norway programme. CINELDI and ZEN also have a shared PhD position, and this candidate defended his thesis in December 2022.

Within the topics of flexibility and energy transition, we have strengthened cooperation with FME NTRANS. In 2022, we organised a workshop series on integrated energy and flexibility markets together with NTRANS. CINELDI also collaborates with FME Include through the project FLEXEFFECT (SINTEF Energy Research).

CINELDI has a collaboration with SFI NORCICS, where Centre leader Gerd Kjølle heads the work package "Demonstration environments". Under this heading is the research objective: Demonstrate new cyber security technologies, applications, methods and models in the cyber-physical electricity system of the future. CINELDI is planning a joint workshop with NORCICS in 2023 to make knowledge about cyber security in the future electricity system available between the researchers and the user partners in the two consortia.

Research and innovation strategy

Research

The research activities are designed to meet CINELDI's main goal of a cost-efficient realisation of the future flexible and robust electricity grid. Our research is performed across four main disciplines: electric power engineering, cybernetics, information technology, and communication technology. These are further supported by social sciences to analyse social economics and consumer behaviour related to flexibility.

The research activities are organised in six research areas. The research areas reflect the main aspects of power system operation and management. This ensures that each area addresses research questions that are highly relevant to both industry and society. Furthermore, it enables academic partners to work in close collaboration across the disciplines. It also facilitates interaction and communication between partners from research and industry alike.

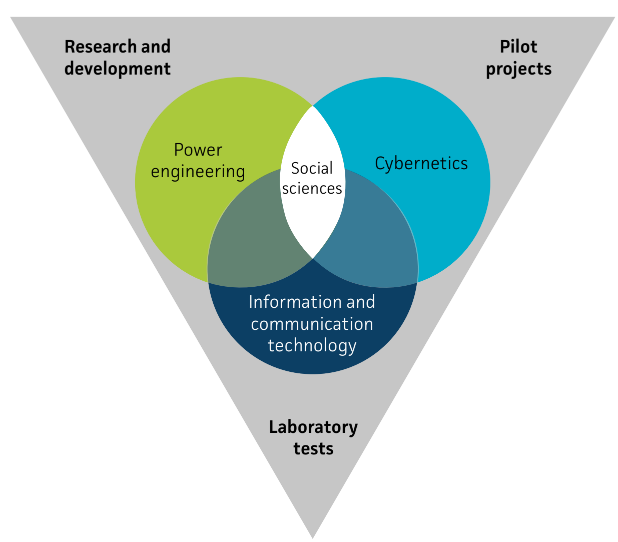
Multidisciplinary research platform

CINELDI's research is based on a multidisciplinary platform consisting of three pillars: research and development, laboratory tests and pilot projects. Through basic and applied research, CINELDI's researchers provide in-depth knowledge, methods, and tools that are then tested in laboratories, simulated environments, and small-scale field pilots (living labs).

Active utilisation of use-case methodology and research infrastructure is an important part of both the research strategy and the multidisciplinary research platform. By using the National Smart Grid Laboratory and living labs hosted by user partners and laboratory tests, we integrate active involvement from the industry partners into our research activities.

Infrastructure: The National Smart Grid Laboratory

The National Smart Grid Laboratory is important for CINELDI's research. The laboratory has been essential for the research area Smart Grid operation, to make a test setup used for testing and development of new technologies for the flexible, intelligent and robust electricity grid of the future. The lab is used by researchers, user partners, PhD candidates and master's students.



Innovation

Innovation is a key factor to succeeding with CINELDI. We define innovations as something *new* that is *useful* and *being utilised*, so that it can create value for society. CINELDI also targets system innovation for the electricity distribution system in our work. System innovation should be perceived as a co-evolution of technical, social, economic and regulatory change.

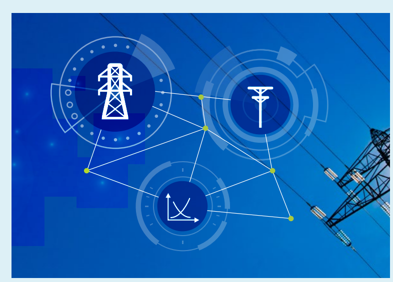
CINELDI's activities are positioned on a scale from targeted basic research and demonstration to novel technology and business opportunities.

Through working with user partners, e.g., in pilot projects, CINELDI creates new spin-off projects across the whole research and innovation value chain, both nationally and internationally. This cooperation helps building capacity to succeed in projects with higher TRL (5-9), e.g., in Horizon Europe projects. Read more about innovation and spin-off projects on page 51.

Research areas

Smart grid development and asset management

Smart grid operation



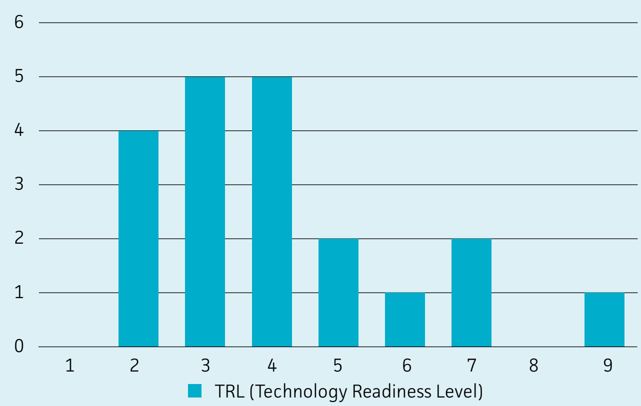
Interaction DSO/TSO

Microgrids/local energy systems

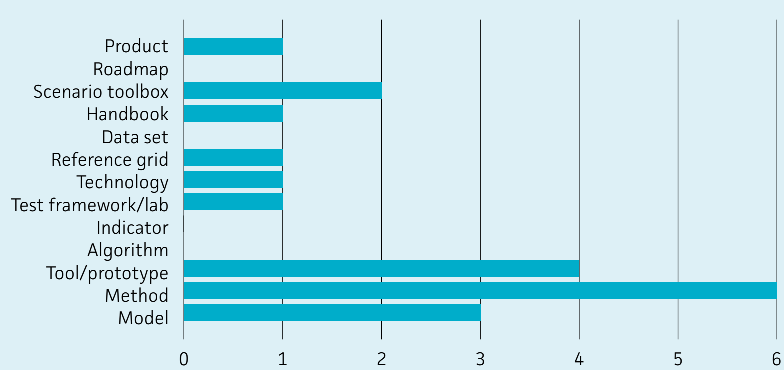
Flexible resources in the power system

Smart grid scenarios and transition strategy

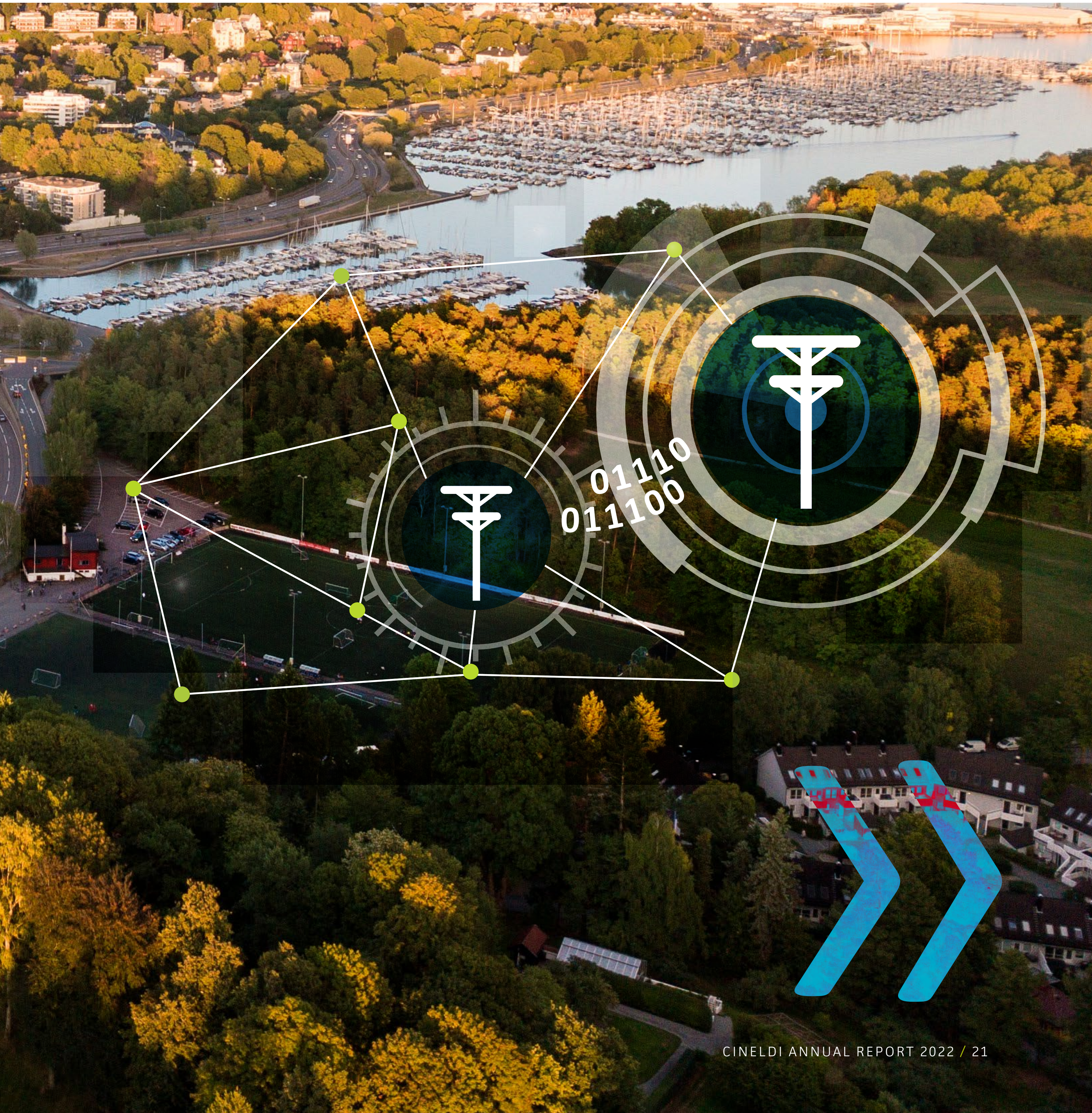
TRL of innovations from CINELDI per Dec 2022



Type of innovations from CINELDI per Dec 2022



Smart grid development and asset management (WP1)



Our primary objective in WP1 is to develop the decision-support methodologies and tools needed for optimal planning and asset management in a smart distribution grid. These methodologies and tools will make the grid more efficient through a better utilisation of both existing and new infrastructure, more target-oriented investments, and better risk control.

In 2022, we continued to extend the framework for planning of active distribution grids by investigating additional active measures and how to deal with uncertainties and risks, as well as developed an approach to identify and assess the impact of cyber security in the grid planning phase.

Active distribution grid planning

The traditional passive framework for distribution grid planning is being augmented to incorporate opportunities provided by new active grid operation technologies, along with the challenges introduced by the active measures such as variabilities and uncertainties.

The extended methodology is now implemented in a Python tool, with the following main improvements:

- Operational models for fast charging stations (FCSs) and local energy communities (LECs) as active measures have been integrated.
- The planning methodology has been further extended by 1) a real options approach to account for the uncertainty in load scenarios and 2) a method for assessing the risk of undervoltage.

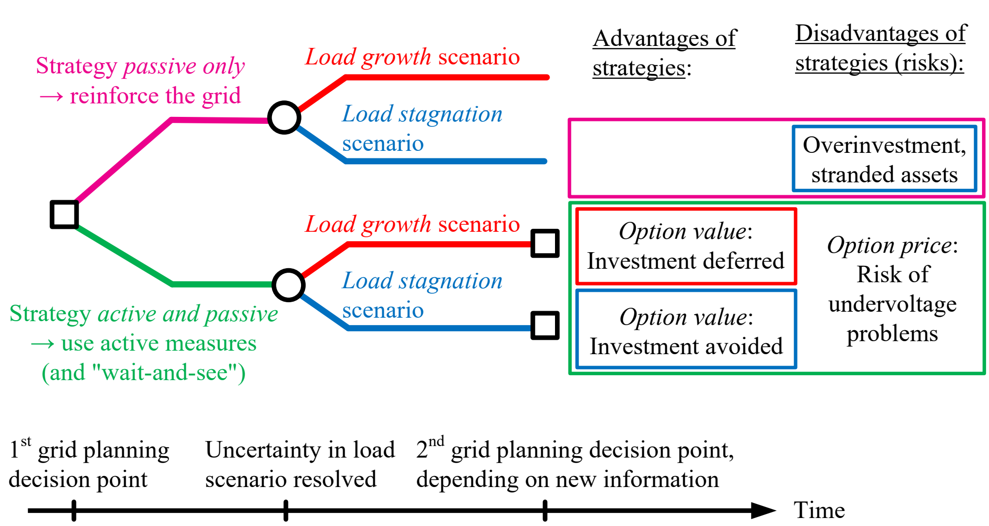


Figure 1 Scenario-based methodology for elucidating risks and real option values

This provides us a model and prototype tool for estimating grid investment needs for combinations of active and passive measures. The methodology and tool have been tested for the CINELDI MV reference system considering the above extensions, providing an illustration of the scenario-based methodology for elucidating risks and real option values of different grid development strategies, see Figure 1.

It is expected that these results can be used in negotiating the price of active measures between the DSO and distribution system actors such as LEC and FCS operators, and the case study illustrates how some risk-taking is required to realise the value from using active measures to manage the long-term uncertainty in load scenarios.

Security of supply in cyber-physical power systems

Power and digital technology is interconnected at various levels throughout the whole power system. Digital components rely on electric power to operate, and the electric power system is becoming increasingly dependent on digital technology to function correctly/optimally. However, this increased digitalisation inevitably means increased cyber-risks for the electric power systems, including vulnerabilities and threats, which may in turn cause harm to security of supply (as well as other assets in the electric power systems). It is therefore important to understand these interdependencies and consider cyber-risks already when assessing and comparing planning alternatives for cyber-physical smart grids. Available information about the alternatives will typically be at a high level of abstraction at this stage, and non-experts on cyber risks must carry out the assessment based on this limited high-level information. Thus, there is a need for a low threshold risk assessment method to assess high-level cyber-risks.

In 2022 we have tested an approach using "Customer Journey Modelling Language" (CJML) to model and assess high-level cyber-risks in the grid planning phase. The method has been tested on a case assuming a hacker gets unauthorised access to a SCADA system and manipulates breakers in a self-healing grid, leading to power outages (attacking security of supply). The corresponding threat model is illustrated in Figure 2.

Preliminary testing suggests that it is possible to create high-level cyber-risk models with limited information about the planning alternatives. Comparison of the different alternatives can be significantly improved if cyber-risks are included already at the planning stage, and better-informed decisions can be made.

In addition, a PhD candidate has completed a version of the simulation tool for evaluating the reliability of cyber-physical distribution systems. The increasing use of renewable energy resources, flexible resources and ICT components in the distribution system requires modification of reliability calculations. The new components are included in the proposed tool, and the distribution system is considered as an active grid using e.g., flexibility measures to maintain or improve power system reliability. The tool package is developed in Python and includes ICT components, flexible resources, and distributed generation.

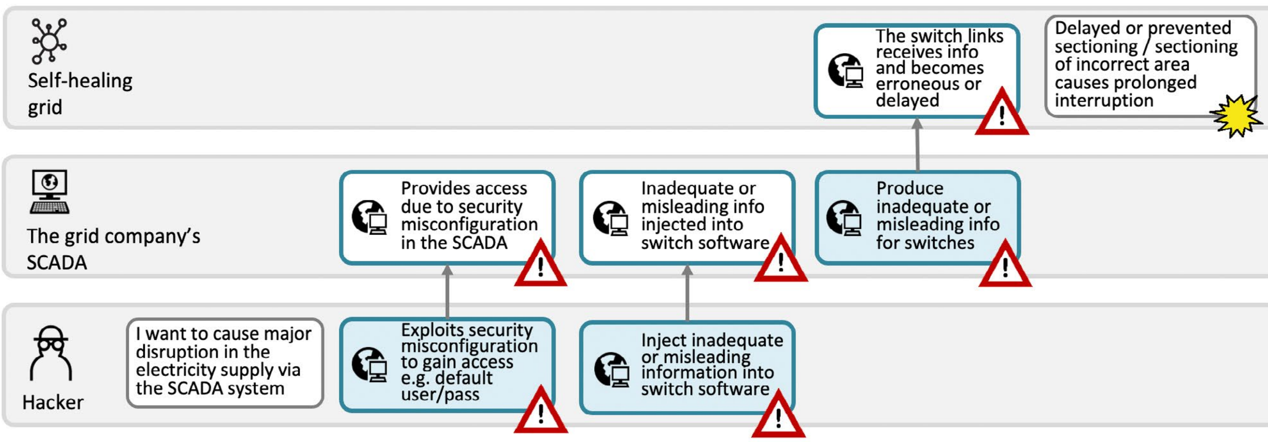


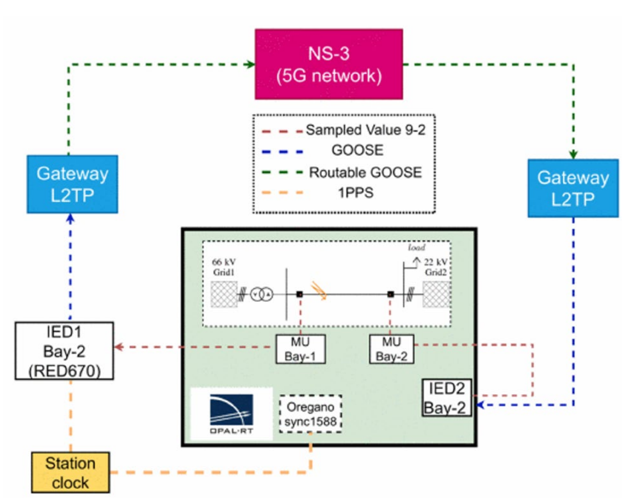
Figure 2: Example high-level threat model illustrating one potential threat scenario where a hacker gains unauthorised access to a SCADA system

Smart grid operation (WP2)

WP2 develops and tests a set of new concepts and solutions that make optimal use of new emerging control and monitoring technologies. These technologies can exploit extensive, real-time monitoring between all assets, grid customers and flexible resources. The expected impact is a more flexible operation of the distribution grid. This will in turn contribute to cost reductions, enhanced energy efficiency, and improved system reliability and security, as well as standardised solutions.

Testbed to assess protection system traffic over 5G networks

The fifth-generation (5G) mobile network promises to offer low latency services. Hence, there is interest in assessing various power distribution grid applications that can be deployed with a 5G infrastructure. However, as these systems are quite new, there is a lack of cyber physical testbeds and tools to assess the use of 5G for smart grid applications such as protection functions. In collaboration with the ProDig project, a real-time testbed has been built to test performances of IEDs and protection schemes under 5G network conditions.



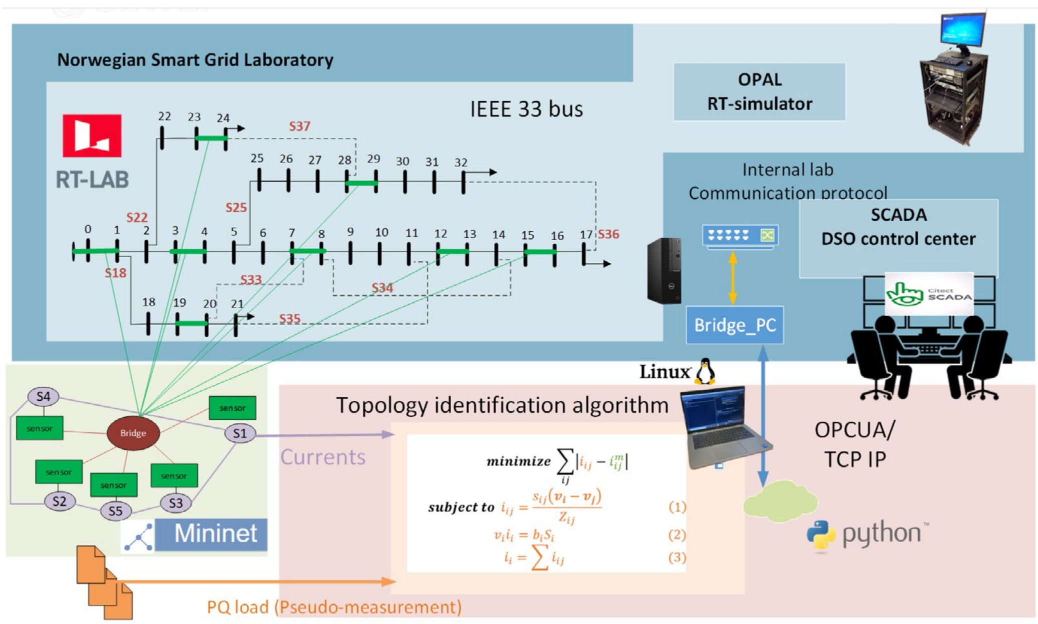
A real-time cyber-physical testbed/co-simulation platform for analysing protection systems is deployed in 5G networks. The network is developed with a 5G emulation based on open-source ns-3 (using 5G New Radio (NR) modules and 4G EPC). The testbed is then characterised by using a testcase of a Permissive Underreaching Transfer Trip (PUTT) protection scheme.

The real-time testbed, especially the network emulation using ns-3, is a low-cost solution that offers researchers in academia or industry the ability to identify network challenges when testing performance of IEDs and protection schemes under 5G network conditions.

Cyber-Physical Power System Testing Platform for Topology Identification

Topology processing is a fundamental part of state estimation process which identifies the real-time configuration of the distribution network. Most advanced network operation functions in turn depend on the awareness of the real-time operational states. A topology identification algorithm is analysed under conditions of errors in the measurements and the pseudo-values inside a cyber-physical power platform.

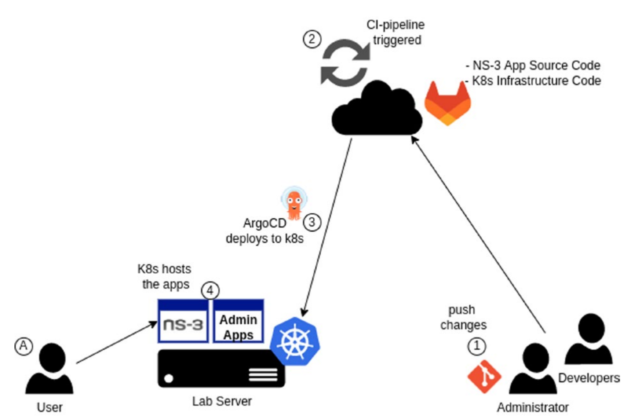
This activity is part of the efforts to increase operational values of smart meter measurements in power distribution systems. The topology identification is one use case demonstrating and developing algorithms focusing also on the utilisation of the Smart meter measurements.



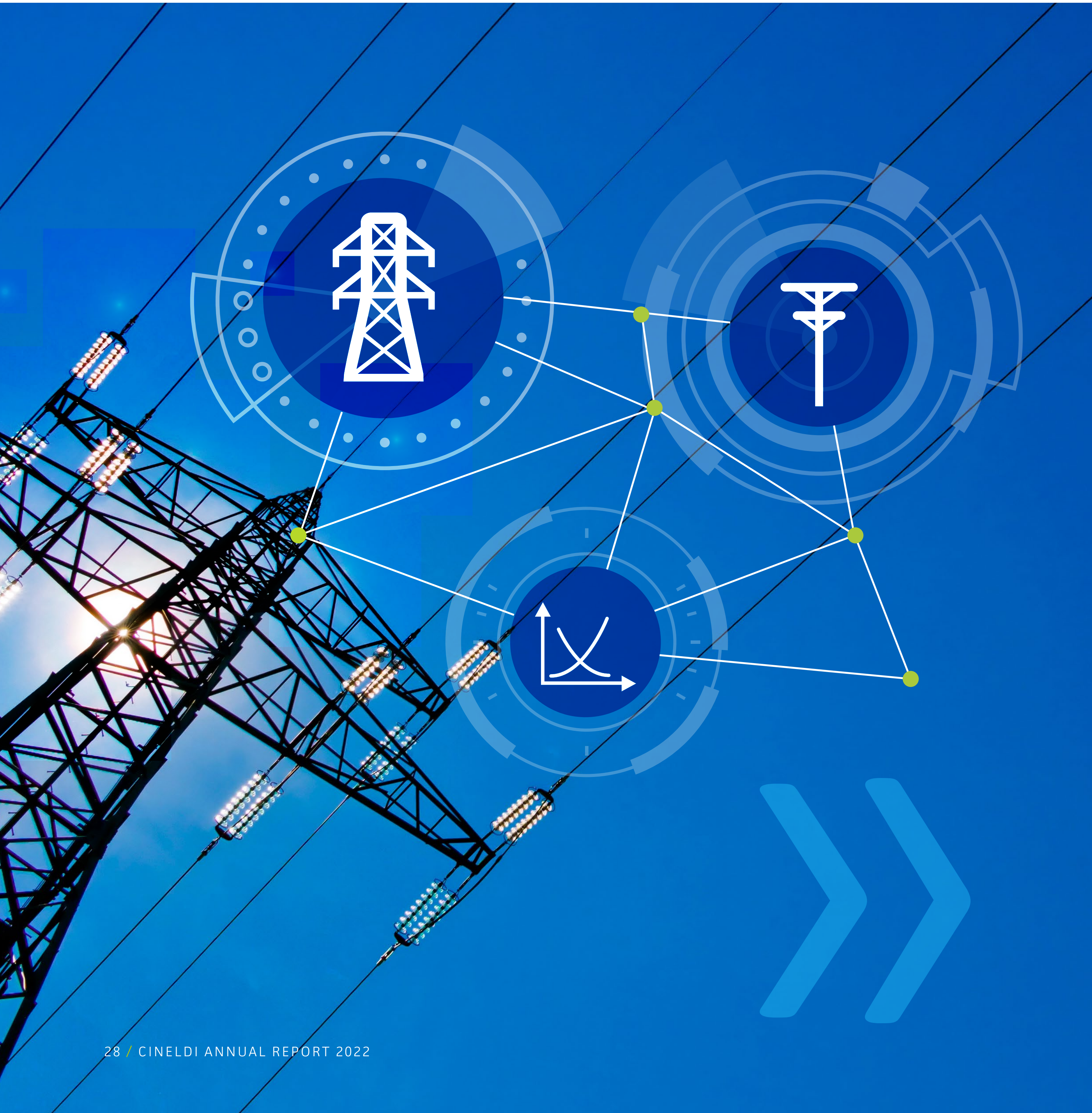
Infrastructure-as-Code SmartGrid lab

A cost-effective laboratory setup with a modern IT platform is beneficial for technology developers and individuals running experiments on communication networks. NS-3 is one such simulator which has been developed to provide open and extensible network simulation platform for networking research and education. The concept of Infrastructure-as-Code enables the automatic creation and configuration of virtual computing resources using prepared scripts. In this work, a self-managed, on-premises Kubernetes platform running ns-3 network simulator solution is developed and installed.

The implementation in the National Smart Grid Laboratory has built Kubernetes Platform as Service (PaaS) from scratch using Cloud-Native Open-Source Software. The focus has been a low-budget on premise alternative to another Cloud-Native PaaS.



Flexibility and Interaction DSO/TSO (WP3)



Through WP3, CINELDI develops methods and models for cost effective integration of flexible resources in smart distribution grid, concepts and solutions for utilising flexible resources in different market products and ancillary services, business models regarding the utilisation of customer flexibility and studies the involvement of consumers and other stakeholders in providing flexibility.

A classification framework for categorisation of barriers for utilising flexibility in the operation and planning of the electricity distribution system was developed in 2022 in cooperation with WP1. The work was based on an interview study with seven Norwegian DSOs in 2021, and focused on mapping barriers and potentials for Norwegian DSOs to utilise flexibility in the operation and management of the grid.

Flexibility can be delivered from different sources (load, generation, storage), and can be used for different purposes by different stakeholders. Further, flexibility can be traded through different markets and incentives. To get an overview of how to utilise flexibility, a holistic approach is therefore required, focusing on the complete flexibility value chain (see Figure 1). The flexibility value chain is used as basis for the categorisation of barriers for utilising flexibility in the operation and planning of the electricity distribution system.

The flexibility value chain starts with the flexibility provider (different flexibility resources, from different types of grid users: households, industry, municipality, …), and ends with the procurer of flexibility (DSO or TSO using flexibility for different grid services). Different business models/agreements, responsibilities and technological requirements for the realisation and activation of flexibility, have to be identified and developed to be able to complete the flexibility value chain and get a holistic overview. Further, the regulatory framework needs to support all stakeholders in the value chain. Identified barriers are presented in Table 1 and mapped in the flexibility value chain in Figure 1.

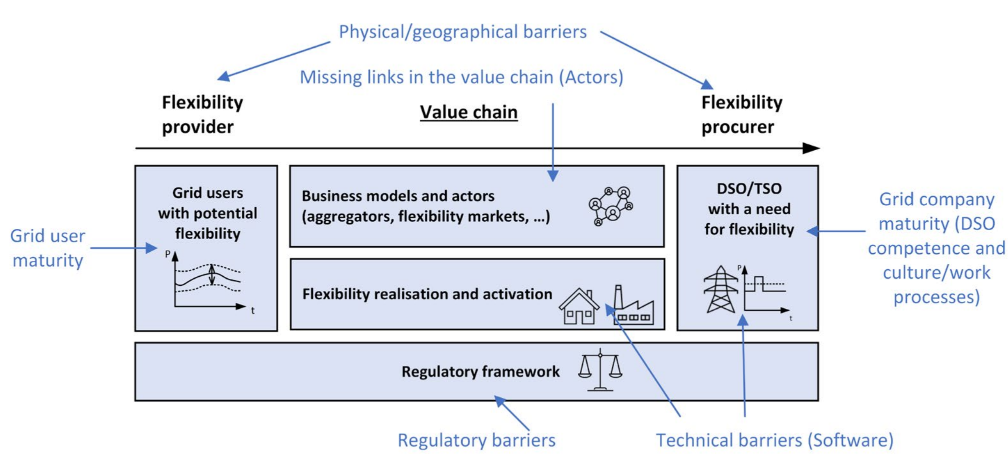


Figure 1 Identified barriers mapped to the flexibility value chain [ref]

Table 1 Main barriers for utilisation of flexibility

Barriers	Related to	Description
Physical/ geographical barriers	Location of flexibility resources and grid related problems	• With a limited number of flexibility resources available today, the probability that these are located in the same place as grid problems to solve, is low.
Technical barriers	Software solutions	• Lack of connections between IT systems for grid operators and grid planners. • Lack of information about actual capacity in the grid (overview in real time).
Missing links in the value chain	Actors and business models	• The aggregator role is not sufficiently developed to utilise flexibility from smaller grid-users (for example household customers).
Grid company maturity	DSO competence	• Lack of competence and tools to estimate predictability and the necessary security margins related to the use of flexibility in long term grid planning. • Lack of competence and capacity to efficiently map potential flexibility and to know which resources to look for, for example, to see if the resources are available in the grid areas where flexibility is needed.
	Culture and work processes at DSOs	• Lack of culture for communication and cooperation between different parts of the DSO organisation (grid planning, operation, customer relations, R&D, contact with authorities, …) • Work processes and procedures are not developed to evaluate flexibility as an alternative (in other words, this is not included in the toolbox for grid planners).
Grid user maturity	Maturity on the customer side	• Grid users have limited knowledge about their own consumption, their consumption pattern, and what it means to act flexibly. • Lack of understanding of cost and benefits related to flexibility, for the grid user, the DSO and society.
Regulatory barriers	Regulation/ framework conditions	• Incentives to realise implicit flexibility (demand response as a result of price response in electricity consumption) are not targeted enough. • Distribution of responsibility between TSO and DSO makes it more difficult for the DSOs to utilize flexibility as an alternative when handling bottlenecks in the regional distribution grid.

Through the interview study, limited use of flexibility for planning and operation of the grid was identified. Use of flexibility was mainly related to pilot projects and through direct contracts with grid users related to grid tariff for interruptible loads.

An overview of flexibility resources considered as relevant by the interviewed DSOs is presented in Figure 2.

Examples of PhD work completed in 2022

A Long-term Strategy Framework for Flexible Energy Operation of Buildings (Kasper Emil Thorvaldsen): Formulation of a general long-term strategy framework for energy management of buildings (LOSTFUTURE). This framework calculates the long-term value of flexibility in residential building and representing long-term price signals into the analysis. The output is multiple future cost curves that showcases the consequence of operation of the energy system for the future.

Designing grid tariffs and local electricity markets for peak demand reduction in distribution grids (Sigurd Bjarghov): Investigating the design of grid tariffs and local electricity markets, focusing on their capabilities of reducing peak demand in distribution grids. Grid tariffs can be designed to impact the peak demand on different grid levels, and capacity subscription tariffs can be combined with coordination from capacity trading in local electricity markets to increase its efficiency and deal with the coincidence factor challenge of price signal design.

Just Flexibility? The Envisioned Role of End Users in Future Electricity Systems (Ingvild Firman Fjellså): Exploration of domestic electricity consumption and expert expectations for more flexible electricity consumption, also known as 'end-user flexibility', to reduce electricity demand peaks, based on qualitative studies.

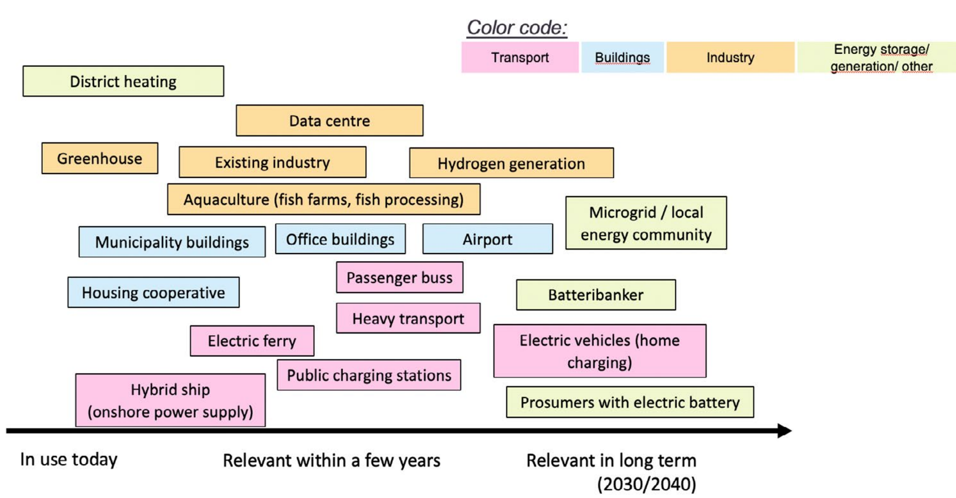
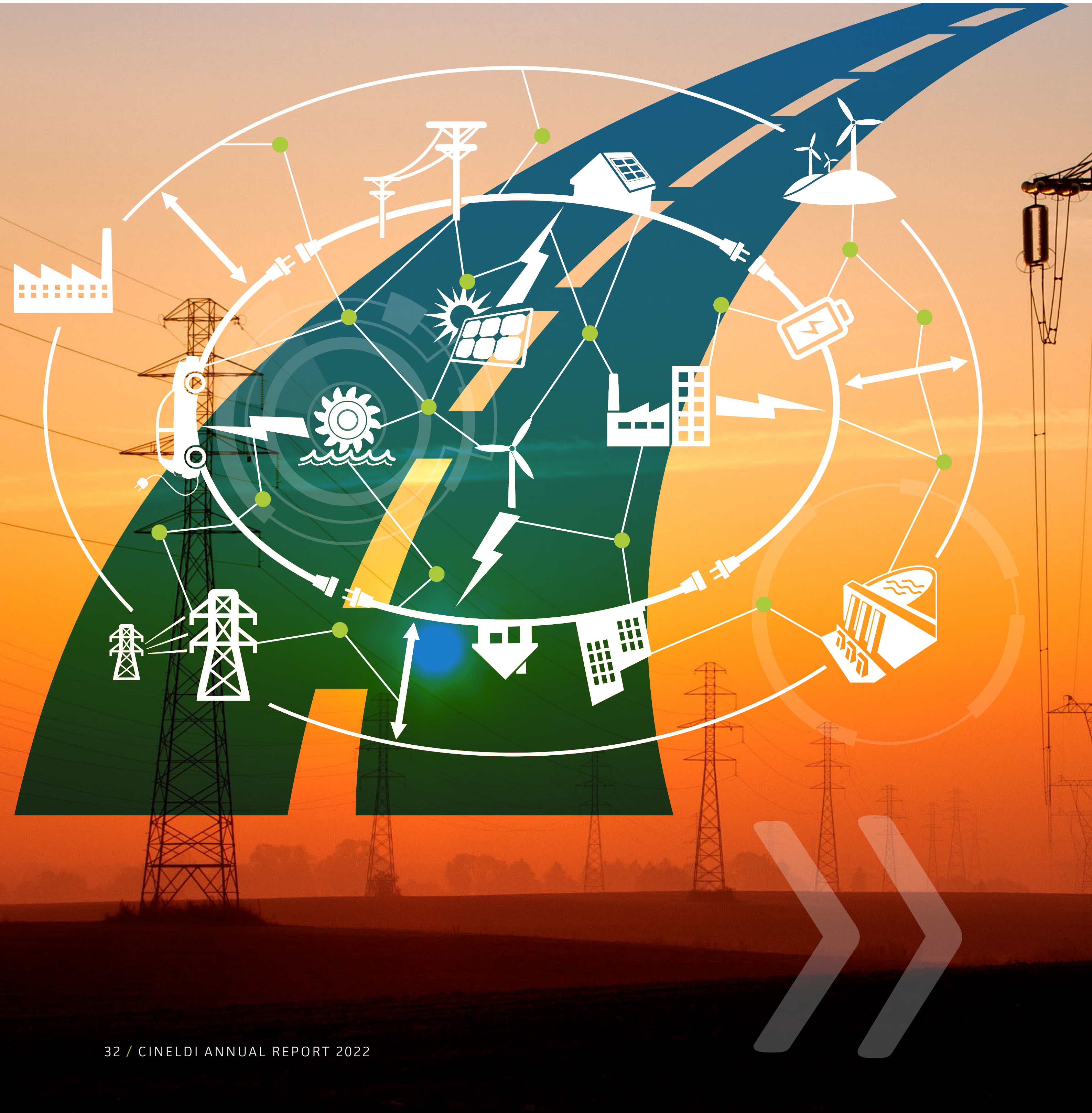


Figure 2 Flexibility potential among different types of grid users - for different time horizons

Smart grid scenarios and transition strategies (WP6)



The electricity grid companies need a robust strategy to make a cost-efficient transition to a flexible, intelligent, and robust grid.

Scenarios and driving forces

In WP6, driving forces for the electricity distribution grid are updated and new mini scenarios are developed in accordance with trends and development since the start of the FME CINELDI.

Some driving forces are strengthened and enhanced (such as climate change and electrification), and geopolitics is a new group of driving forces.

New mini scenarios are developed related to digitalisation, electrification, flexibility, and security of electricity supply. The driving forces and mini scenarios provide a foundation for developing appropriate strategies for the transition towards a flexible and intelligent electricity distribution grid that is also robust and cost-efficient.

Reference grid

To support the transition strategy, WP6 has developed reference grids that represent real Norwegian distribution grids. International test grid data sets are typically made for academic purposes, and for verifying and validating new methods. However, they are often not suitable for studying realistic problems. Therefore, it is important to establish reference grid data sets that are representative of Norwegian distribution grids.

Reference grids enable technologies, scenarios, and challenges to be tested in realistic environments. They may be used for comparison purposes, as well as for quantifying the socio-economic costs of the future grid in relation to investments, operation, power supply interruptions and electrical losses in different scenarios. Moreover, reference grids may be used to show the effect of new technologies and solutions, as well as quantify benefits and potentials to save costs.

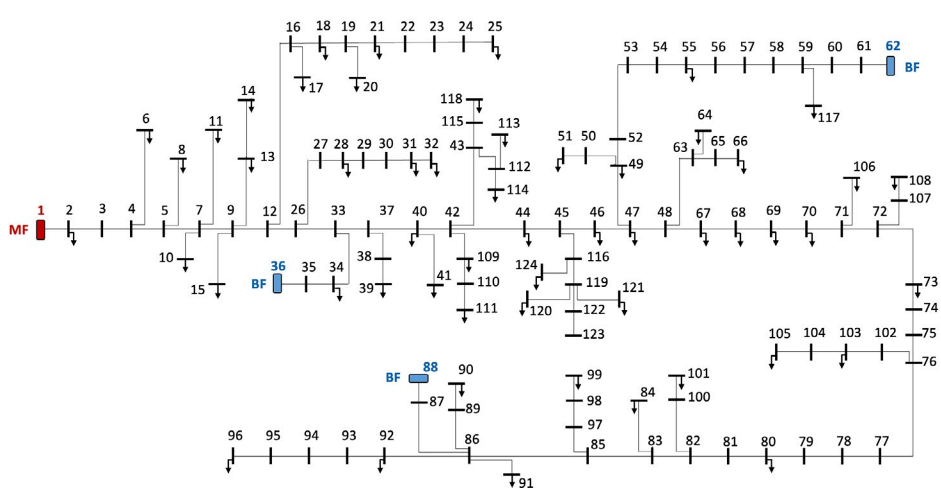


Figure 1 The CINELDI MV reference grid

The reference grid can also visualise appropriate measures for integrating new elements – such as distributed renewable power generation, charging stations for electrical vehicles, and new types of electricity consumption – and for dealing with any challenges that might occur. This enables more fundamental analyses, as well as analyses of new problems in the future grid.

In 2022, a reference grid data set is made available to be accessed by other researchers and stakeholders and it is in use in different case studies in CINELDI. The basic reference grid is shown in Figure 1.

The basic reference grid data set is further extended to produce a data set that is relevant to study utilisation of flexibility. For this purpose, new elements are integrated in the reference grid (as shown in Figure 2) to simulate many of the issues that we expect to be dominant in the future distribution system:

- Local energy systems/communities with PV power production, charging for Electrical Vehicles, local storage, etc.,
- Large storage units like batteries,
- Power intensive charging stations for electrical vehicles defined by number of charging points and total capacity,
- Electric ferry charging points for different needs, governed by the ferry timetable,
- Wind farms with intermittent power production.

In addition, the grid has alternative supplies from back-up feeders.

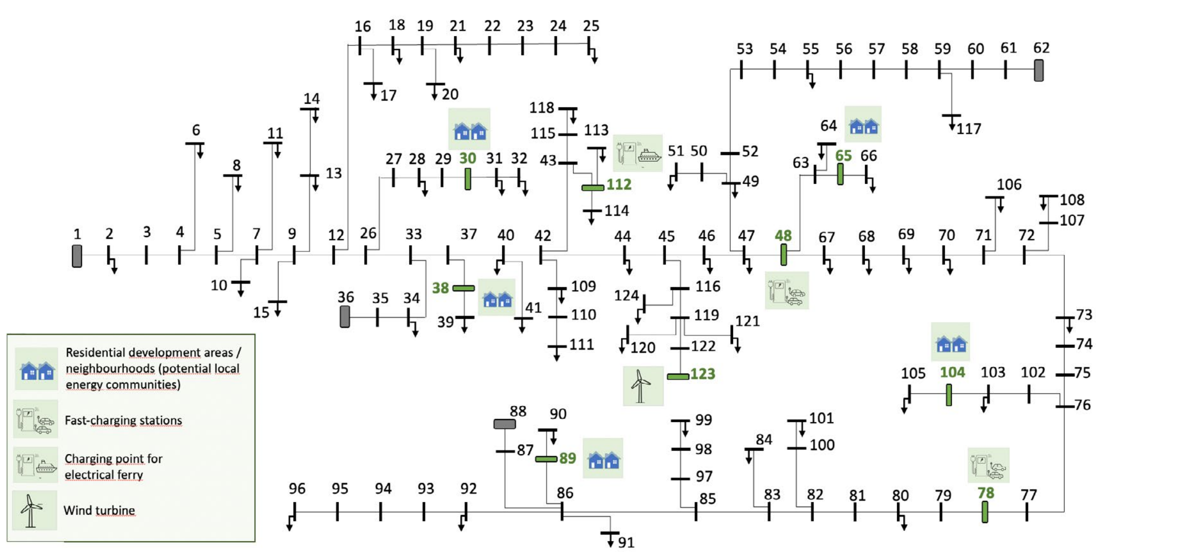


Figure 2 The CINELDI MV Reference grid – Flexibility case.

Photo: Falkeblikk

Pilot projects

We conduct pilot projects in real-world environments to test and validate new research findings, technologies, and solutions for the upcoming intelligent electricity distribution system. Pilot projects can contribute to system innovations, as well as aid in the establishment of standardised and cost-effective solutions for the future distribution grid. In addition, pilot projects will contribute to the transition strategy of WP6.

The projects are organised into four priority areas: application of AMR/grid data, flexibility, fault handling and self-healing and sensing and digital monitoring.

CINELDI partners are involved in approximately 20 ongoing pilot projects. These range from testing new technologies and algorithms, to testing new tariffs and flexibility markets. Some pilot projects have already been finalised, and their results put into practice through our innovations. There is also a large potential for more innovations to result from the ongoing pilots, as well as new spin-off projects.

In 2022, we initiated the last two pilots and prioritised completing the ongoing ones. We placed significant emphasis on documenting the results and innovations from these pilots.

A large-scale research pilot project with our new partner, Heimdall Power, aiming at testing their neurons at a system scale, really got off the ground this year. Installation of neurons is ongoing, and data is being collected as we speak.

Over the course of 2022, we shared developments from the pilots through four pilot project expert meetings, additional webinars and presentations at CINELDI events. A priority in dissemination activities moving forward is to communicate pilot project results to more partners than the ones directly involved in the project, to enable them to implement results and innovations themselves.

Overview of pilot projects in CINELDI

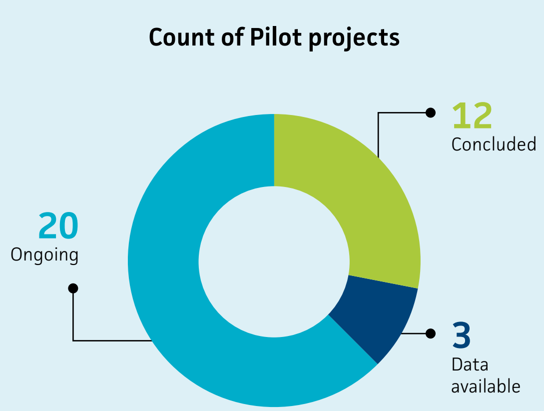
The status and number of pilot projects in the four priority areas is shown below. The number in parentheses refers to the map:

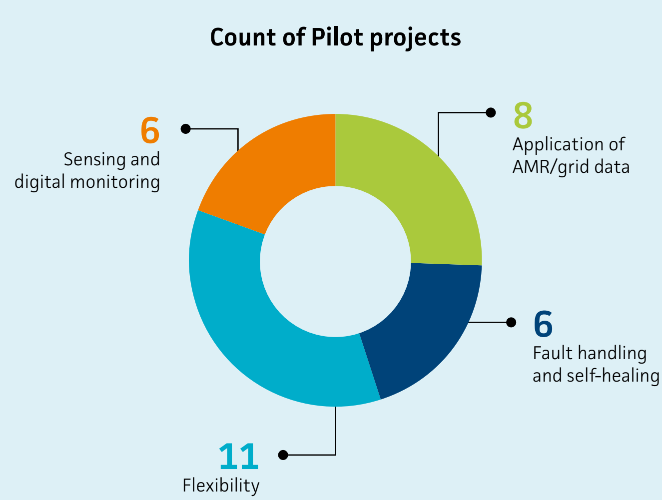
Application of AMR/grid data

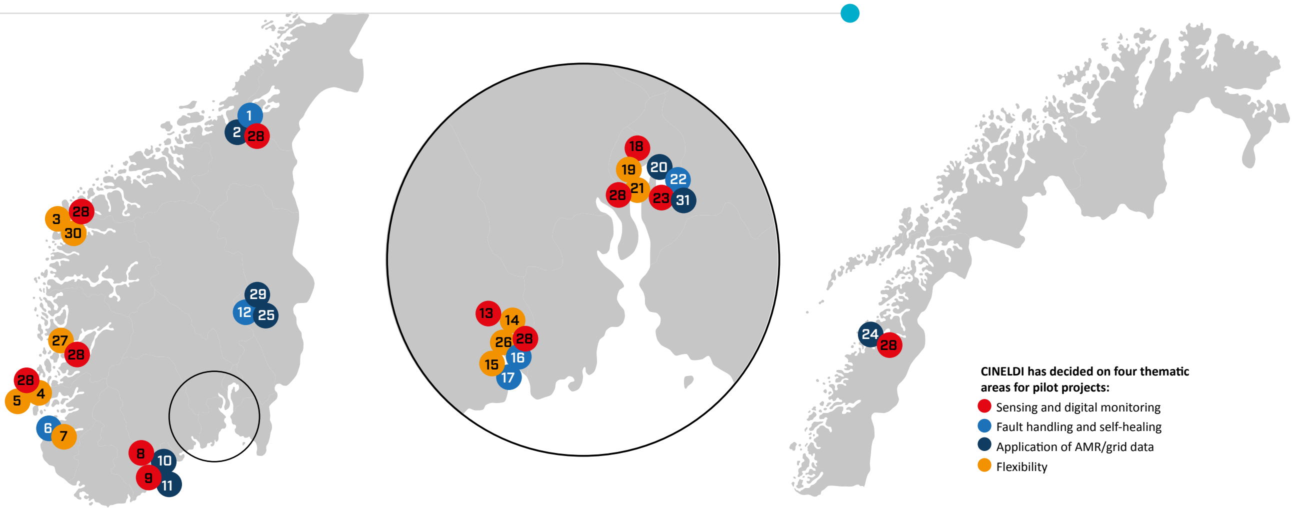
- Added value from Smart meters - Aidon - (2)
- Risk-based distribution network planning - Agder Energi Nett - (10)
- Predicting peak load in secondary substations - Agder Energi Nett - (11)
- Probabilistic planning methodology - Norgesnett - (20) Finalised
- Development area Molobyen - Arva - (24) Finalised
- Data-Driven Failure Risk Assessment for Predicting maintenance - Elvia - (25) Finalised
- Detection of earth faults based on data from smart meters - Elvia - (29)
- Creation and use of management data in 3D in the field - Elvia (31)

Fault handling and self-healing

- New relay concept - Elvia - (1)
- Automated recoupling in smart secondary substation - Lnett - (6) Finalised
- Faster fault location - Elvia - (12)
- An algorithm for self-healing - Lede - (16)
- Fault indicators - Lede - (17)
- Fault handling and self-healing - Elvia - (22)







Flexibility
- NODES flexibility platform - Linja - (3)
- Flexibility market - Fagne - (4)
- Utsira: An islanded grid on an island - Fagne - (5)
- Batteries as voltage support- Lnett - (7)
- Optimisation of local balancing with battery - Lede - (14)
- Transition to and from island mode - Lede - (15) Finalised
- Active homes - Elvia - (19) Finalised
- iFleks - Statnett - (21)
- Fast Frequency Reserve - Lede - (26) Finalised
- Energy management in BKK Nett - BKK Nett - (27)
- Identifying flexibility with AI - Embriq - (30)

Sensing and digital monitoring
- Machine learning in grid inspection - Agder Energi Nett - (8)
- Digital Inspection - Agder Energi Nett - (9)
- Digital Inspection - ABB Electrification - (13) Finalised
- Smart Cable Guard - Elvia - (18) Finalised
- Digital Inspection - Elvia - (23) Finalised
- Flexible power grid by dynamic operation - Heimdall power (28)

New method from Aidon for utilising data from smart meters

Aidon, together with Lnett and SINTEF Energy Research, have developed a new method for automatic earth fault detection, analysis and fault correction. This work has been done in WP2.

The method is based on measures from smart meters and consists of algorithms for analysis and detection of fault locations in maps. The accuracy of the analysis is calculated, and if this is sufficiently good, an automatic process is started for information exchange and error correction between the network company, customer and electrician.

The method is based on smart meter data and a solution for analysis developed by Aidon, with integration between different specialist systems at the power grid company.

The next step is further development of the analyses and testing in controlled conditions in the National Smart Grid Laboratory. Field testing and establishing a proof of concept for verification of expected results is also important in the further plans.

2022

Winner of CINELDI prize

Rolf Pedersen of Aidon is the 4^{th} recipient of the annual CINELDI prize. He was awarded the prize for his contribution to promoting research collaboration, innovation, communication, user involvement and internationalisation within intelligent energy distribution.

One step closer to a self-healing grid

Fault detection and location is a key functionality in self-healing, and it is the first step in the automation of the fault handling process.

In the pilot project "New Relay Concept", a new idea for fault localisation from Elvia has been tested with simulations and in experiments at the National Smart Grid laboratory. The pilot won the CINELDI prize in 2018.

We developed two new methods to automate the fault handling process in distribution grids focusing mainly on the capability to accurately locate faults so that maintenance and restoration of the service can be done as quickly as possible.

Faults in the electric grid are inevitable and cannot be avoided. The distribution grid will always be at risk of power outages caused by weather, wildlife, falling trees, human error, malicious attacks, etc. Hence, the grid's design and operation should be resilient against the inevitable occurrence of faults. In this regard, one of the key features of smart grids is the self-healing capability to automatically detect, locate and isolate faults, and restore service within a very short time; from milliseconds to seconds. This is called Fault Localisation, Isolation and Service Restoration (FLISR). In contrast, for conventional (current) distribution grids, the fault location and service restoration have to be done manually and such maintenance works may take hours, with large numbers of customers affected.

The two earth fault location methods are based on the sequence component of the current and a neutral voltage measurement at a primary substation. The first method is based on the utilisation of the change in negative sequence currents, while the second method utilises the change in zero-sequence current and neutral voltage measurement. The methods are simple to use and implement as they are based on a simple logic that utilises current and neutral voltage measurement at a primary MV substation.

Both methods were tested on a simulated grid based on data provided by the Norwegian grid operator, Elvia. The simulation results show that the methods have very good accuracy in locating earth faults, where the distance estimate error is within a few hundred meters. The prediction performance of both methods was investigated considering different scenarios where the fault resistance, load asymmetry and measurement errors were varied. Both methods performed well and showed good accuracy in all the scenarios.

The methods developed are generic, which means that they can be used to locate other types of short circuit faults.

The results are published in the journal Electric Power System Research: "Two novel current-based methods for locating earth faults in unearthed ring operating MV networks". Testing of the methods in a laboratory setup is the next step, and we want to do a pilot test on a real power grid in collaboration with Elvia.

Read more about the new methods at #SINTEFblog.

Innovation

Innovation is a key factor for success with CINELDI. We focus on the research-driven innovation chain, from "blue skies research" to pilot projects and testing at a lower TRL. Our ambitions are also to contribute to innovations through spin-off projects (see page 51) and through new research projects, both national and international, that contribute to CINELDI's goals along the entire R&D innovation chain. We also expect several of our innovations to leverage business opportunities for technology providers in both Norwegian and international markets.

At the end of 2022, CINELDI had more than 130 scientific results. We have also identified 35 innovations so far, seven of which were identified in 2022. Examples are added value of smart meters, a novel method for detecting earth faults, classification of flexible resources, and a simulation tool for reliability of supply analysis.

Revolutionary technologies and methodologies mean very little if no one is willing to put them to use, if they're too expensive, or if regulations prevent them from being applied. Therefore, we target system innovations - co-evolution of technical, social, economic and regulatory change - for the electricity distribution system.

Innovation is something new, that can be useful and utilised for value creation. An important part of our innovation activity in 2022 has been to make results available to be utilised for enhanced value creation by the user partners, introducing new or improved work processes, methods, or models.

Our check list for evaluation of new results from 2021 is important in this work. The check list asks questions about what is needed to put a result into use and what are the most important barriers. This work was supported by our innovation committee consisting of user partners. The committee contributes to evaluating results and innovations and considers how these can be taken forward in various types of spin-off-projects. They also facilitate good user partner involvement and dissemination of results.

CINELDI's innovations*

Flexible Load Analysis – a code platform for load modelling and analysis

The code platform "Flexible Load Analysis" is an open-source tool developed in a CINELDI pilot project in collaboration with the Norwegian DSO Norgesnett. The tool can process and analyse grid data and load time series for connection requests and grid planning purposes. Using the code platform, the DSO can add a new customer to the grid with a given load behaviour and visualise the load in the grid and how it develops with time, and visualise when, how often and how much a chosen grid asset is overloaded. The load in the grid can be analysed on an individual or aggregated level, identifying key information such as peak load and coincidence factor. The code platform also has functionality to anonymize grid and load data.

FACTS

FACTS

TRL: 4-5

Target group

- DSOs/TSOs
- Technology providers
- Researchers and consultants
- Educators

Simulation tool for reliability assessment of modern distribution systems – RELSAD

Increased penetration of renewable energy sources leads to power varying more over time, and analysing the power system under different conditions is important for assessing the reliability of the system. RELSAD is a Monte Carlo based simulation tool calculating reliability in distribution systems. It is specifically developed to account for dependencies between power and ICT systems (cyber-physical systems), and implementing active components such as distributed generation, batteries, microgrids, and electrical vehicles with possibilities for vehicle-to-grid services.

FACTS

FACTS

TRL: 6

Target group

- DSOs/TSOs
- Technology providers
- Researchers and consultants
- Educators

* Innovations that are presented at our web page so far. In 2023 we will continue working on presenting all our innovations.

Scenarios for the future electricity distribution grid

To better understand the complexity of the future distribution grid, we identified and structured the driving forces for distribution system innovation. Based on these driving forces, we developed a repository of about 100 mini scenarios.

Using a two-dimensional system of coordinates, we have built four plausible scenarios for Norwegian electricity distribution grids in 2040. The horizontal axis describes the grid costumers and the degree to which they contribute flexibility. The vertical axis describes the degree of digitalisation and automation of the grid and grid management. This enables us to prepare for an uncertain future.

FACTS

TRL: 3

Target group

- DSOs/TSOs
- Technology providers
- Member organisations
- Market operators
- Researchers and consultants
- Educators

Checklist for evaluation of results

Long-term knowledge building research is mostly conducted in lower TRL projects, while pilot projects typically produce results that are higher on the TRL scale. However, turning research into innovation requires work in multiple areas. CINELDI has developed a checklist that considers a research result's target groups, benefits, and sustainability contributions. It can also be used to evaluate what is needed before results can be applied as innovations. Moreover, the checklist provides insight to potential barriers and suggests barrier-reducing measures, and maps possibilities for further research and spin-off projects.

FACTS

TRL: 5

Target group

- DSOs/TSOs
- Technology providers
- Member organisations
- Market operators
- Researchers and consultants
- Educators

Comprehensive classifications and characterizations of flexible resources

Power system flexibility is essential for coping with the uncertainty and variability of power generated from PV sources and the wind. Based on an extensive literature review, a unified definition, characterization, and classification of flexibility resources was proposed in paper. The paper showcases how the clear characterization of flexibility resources can be used to map different ancillary service needs to the relevant group of flexibility resources.

FACTS

TRL: 2

Target group
- DSO/TSO
- Researchers and consultants
- Educators

Planning framework for active distribution grids

The long-term planning frameworks currently used by electricity distribution grid companies are not designed to account for more variability and new uncertainties due to e.g. variable distributed generation. The solution? An adaptation and extension of the traditional grid planning framework in the Norwegian handbook on power system planning and the active distribution grid planning framework by CIGRE WG C6.19., among other innovative elements like more detailed modelling of the variability. This allows for active grid measures and related technologies to be considered consistently along with traditional measures in distribution system development, which may lead to cost reduction.

FACTS

TRL: 4

Target group
- DSOs/TSOs
- Researchers and consultants
- Educators

Method for cybersecurity risk analysis customized to smart grids

Smart grids are socio-technical systems characterised by complexity, interdisciplinarity and dynamics, introducing new risks that have not previously been dealt with. To improve decision making in this complex system, we need an efficient risk analysis.

We have developed a new method that provides an easy-to-understand risk picture. The method will improve our understanding of the effects of power grid digitalisation on cybersecurity, and provide decision support for managing reliability of power supply and cybersecurity. This in turn improves the security of supply. The approach is based on parts of the "CORAS" method for risk analysis.

FACTS

TRL: 7

Target group

- DSOs/TSOs
- Technology providers
- Member organisations
- Researchers and consultants
- Educators

State estimation algorithm for monitoring distribution grids

Power system state estimators play a critical role in modern power grids. However, state estimation cannot be easily achieved in smart grids. Therefore, we have developed a simultaneous input and state estimation method (SISE) to estimate the states of a partially known system with system-wide unknown inputs. The method can be used for several purposes: to prevent system-wide failures or blackouts, tune power system stabilizers, or to improve the reliability of system models utilised for dynamic security assessment (DSA), and to design state estimator-based fault detectors.

FACTS

TRL: 2

Target group

- DSOs/TSOs
- Technology providers
- Researchers and consultants
- Educators

Concept for delayed integrity check of PMU measurements

Future power system operation is expected to rely on the use of synchrophasor measurements (PMU). The IEC 61850 standard defines communication protocols for electrical substations, including synchrophasor measurement transmission. However, it does not properly address cyber security, leaving this critical infrastructure highly vulnerable to cyberattacks. We have developed a novel mechanism for a delayed integrity check of synchrophasor measurements. The solution manages to detect when integrity is compromised, without adding any overhead or delay to the time-critical synchrophasor transmission itself.

FACTS

TRL: 3

Target group

- DSOs/TSOs
- Technology providers
- Researchers and consultants

Real-time power hardware-in-the loop microgrid simulation platform

Microgrids contain distributed generators, energy storage systems, controllers and passive loads, wherein the components and controllers have different characteristics. Therefore, the interaction of all these devices and their controllers results in very complex systems where the dynamic performance may be unpredictable. To test the closed loop interaction of these devices, we have installed a power hardware-in-the-loop (P-HIL) simulation facility at the Norwegian National Smart Grid Laboratory. P-HIL is a virtual simulated system and actual hardware coupled together using a real-time simulator plus a power amplifier. This approach offers high flexibility, which can extend the test coverage compared to a prototype or even full-scale testing.

FACTS

TRL: 7

Target group

- DSOs/TSOs
- Technology providers
- Researchers and consultants
- Educators

Virtual Oscillator Control

Synchronisation in island electrical grids dominated by power electronics is a challenge due to the absence of a grid reference to follow, lack of inertia sources and the usual lack of communication among the units. A new technique for synchronisation of Voltage Source Converters in microgrids has been developed. The technique was successful in cases where the conventional droop controller failed. The results provide convincing evidence for the adoption of a more complex controller as the Virtual Oscillator Control in island grids will naturally be more vulnerable to voltage distortions.

FACTS

TRL: 3

Target group
- Technology providers
- Researchers and consultants
- Educators

Energy storage and RES representation in multi-period optimal power flow

The optimal operation of a distribution system with energy storage can be formulated as a multi-period optimal power flow (MPOPF). The challenge is to decide when to charge and discharge the storage, taking into account grid constraints , wind and PV uncertainties. We have developed a method for storage valuation inspired by optimization principles from hydropower scheduling, including the energy storage model in MPOPF, together with stochastic wind and PV. This is relevant for DSOs facing new challenges when planning and operating their grid, such as increasing amounts of prosumers with PV and batteries and increasing amounts of medium-scaled distributed generation, such as smaller wind farms and solar PV farms.

FACTS

TRL: 4

Target group
- DSOs/TSOs
- Technology providers
- Member organisations
- Market operators
- Researchers and consultants
- Educators

BATTPOWER Toolbox: memory-efficient and high-performance multi-period AC-optimal power flow solver (AC OPF)

Energy storage and flexible demand makes AC OPF computations very challenging to solve, and computation time is an issue when using commercial or free optimisation solvers. Our solution is to derive a tailor-made optimisation solver for the problem, utilising the structure of the underlying mathematical formulation of the system. This innovation is relevant for DSOs facing new challenges in the planning and operation of their grid, e.g. increased amounts of medium-scaled distributed generators.

FACTS

TRL: 4

Target group

- DSOs/TSOs
- Technology providers
- Market operators
- Researchers and consultants
- Educators

SDP model for operation planning of flexible resources in buildings

When considering future long-term operational costs, it can be crucial to include the future impact of current decision-making within building energy system scheduling. We have made a long-term operational model inspired by water value calculation in hydropower. This captures the future impact of current decision-making through the use of non-linear cost curves. The model can be further developed into a practical operational tool for scheduling of building energy systems.

FACTS

TRL: 3

Target group

- DSOs/TSOs
- Technology providers
- Member organisations
- Market operators
- Researchers and consultants
- Educators

Method for analysing communication failures in smart grids

The power system's high dependency on ICT establishes new interdependencies and vulnerabilities that need to be properly analysed. We have developed a novel dependability analysis method that combines Stochastic Activity Network (SAN) modelling and numerical analysis. The method application returns a set of metrics that assess the impact of ICT architecture vulnerabilities, cyber-physical system interdependencies, and dependencies on environmental conditions on Wide Area Measurement Systems (WAMS) data accuracy. The software represents a valuable tool for assessing ICT architecture capability to reliably deliver data for correct monitoring.

FACTS

TRL: 3

Target group

- DSOs/TSOs
- Technology providers
- Researchers and consultants

Data-driven flexibility model for shiftable atomic loads

Modelling flexibility can be a difficult task, especially when it involves the considerations of user habits. Appliances such as dishwashers, washing machines and tumble dryers are sources of flexibility, as the frequency of use and the selected program during operation can vary greatly. We have developed a data-driven model that utilises statistical data and other previously available time series measurements to extract the required features in the calculation of the expected flexibility potential as well as rebound effects after activation. Network operators may use it in their operation and/or long-term plans.

FACTS

TRL: 4

Target group

- DSOs/TSOs
- Technology providers
- Member organisations
- Market operators
- Researchers and consultants
- Educators

Method for cost-benefit analyses of batteries in distribution grids

Batteries can be deployed at strategic locations in the grid, and perform active and reactive power control to achieve a better utilisation of the grid as an alternative to reinforcements. We have established a general framework suited for grid planning incorporating batteries. The proposed methodology is the first step towards a holistic planning approach for grids, where batteries can help mitigate congestions and other problems.

FACTS

TRL: 7

Target group

- DSOs/TSOs
- Technology providers
- Member organisations
- Researchers and consultants
- Educators

Driving forces and mini scenarios for the future distribution grid

The interaction between various technological, regulatory and social factors add complexity to the future electricity grid that needs to be addressed in a holistic and coordinated way in order to support the system innovation. To better understand the complexity of the future Norwegian distribution grid, the driving forces for system innovation have been identified and structured. Based on the driving forces, a repository of 109 mini scenarios have been developed. The driving forces and mini scenarios can be used as input to strategic processes such as grid development, competence building, R&D strategy, etc.

FACTS

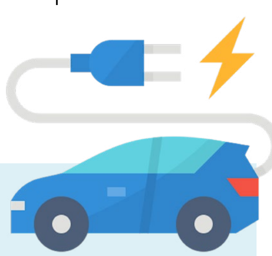
TRL: 2

Target group

- DSOs/TSOs
- Technology providers
- Member organisations
- Market operators
- Researchers and consultants
- Educators

EV power share charging system

Charging electric cars in an area can cause major power surges both locally and in the grid. A system incorporating POWER SHARE means that power for charging can be regulated dynamically, based either on a maximum value for the respective circuit or on input signals that regulate the maximum value for all cars. With the power share solution, it will be possible to control the maximum load either statically, by setting a fixed maximum value, or dynamically, based on other consumption for the same master fuse, data from smart transformers, or the requirements in the network in general, based on the published ACOPF algorithm.



FACTS

TRL: 9

Target group

- DSOs/TSOs
- Technology providers
- Researchers and consultants

Spin-off projects

CINELDI actively contributes to applications for spin-off projects that contribute to building the electricity grid of the future.

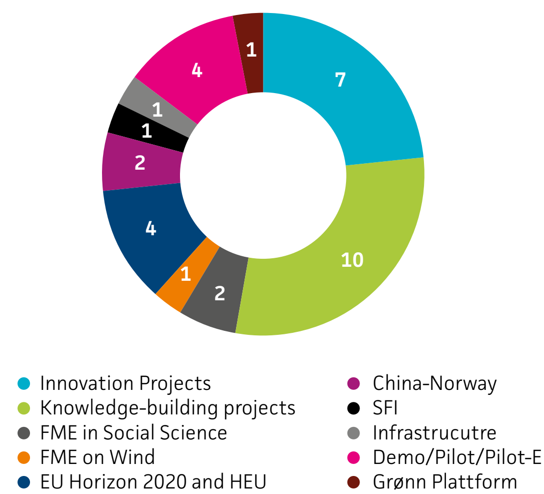
Between 2017 and 2022, 69 CINELDI-supported applications were submitted. By the end of 2022, 66 applications had been evaluated and 34 were granted, a success rate of 51,5 percent.

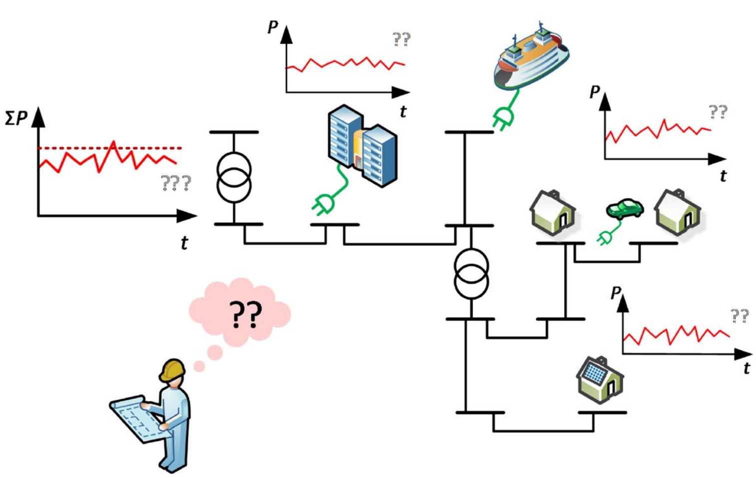
In 2022 we contributed in applications to an IPN-project, a Pilot E-project, one application to the Green Platform (GP) Initiative, in addition to several EU-applications and one INTPART-project. Among these, the GP NextGrid, the IPN FORSEL and the Pilot-E project Flex-E were granted.

GP Next Grid shall prepare the grid companies' operation centres for the future's complex and automated operation of the power grid.

IPN FORSEL will develop tools and methodologies that will help Norwegian grid companies to utilise the opportunities for flexibility in the power grid and make good choices when it comes to future load and the connection of new electricity customers to the power grid.

Flex-E will find solutions that can relieve stress and provide flexibility during the most intense hours in the power system. Flexible resources, business models and how this can be used by both network companies and system operators is important research topics.





International cooperation

Ever since project launch, we have aimed to establish CINELDI as an international reference project in the field of flexible, intelligent, robust, and cost-efficient electricity distribution grids for the future.

To do that, we cooperate with leading international smart grid scientists, projects, research institutions and universities. Senior researchers from CINELDI are co-supervisors for PhD students and acts as opponents of PhD dissertations.

Our own research scientists also actively participate, organise and hold keynote speeches at international conferences such as Probabilistic Methods Applied to Power Systems (PMAPS), the International Conference on The European Energy Marked (EEM) and the CIGRE Paris Session.

Cooperation through webinars

Instead of hosting the planned annual international conference, which was cancelled for the third consecutive year due to travel restrictions, we initiated an international webinar series in September. The webinar series aim to achieve the goals set for the international conference. Our goal is to enhance the centre's international visibility and establish relevance and appeal on the global stage by inviting distinguished researchers to deliver presentations on the webinar topics. The series will continue in 2023.

The webinar series has also led to specific professional collaborations; The leader of the work package on Smart grid operation was invited to a workshop at the National Renewable Energy Laboratory (NREL) in USA. NREL has Smart Grid laboratory activity, and through this connection we have established a basis for further collaboration.

Cooperation through other projects

Several members of the Centre Management Team participate in and lead working groups and study committees in organisations such as CIGRE, ISGAN, IEA and EERA JP Energy Systems Integration. In 2022, ISGAN started an International Knowledge Sharing Project with the title "Network Planning and Decision-Making under Uncertainty". CINELDI is represented by one of our leading researchers, who was appointed as "Key National Stakeholder".

We are collaborating with the University of Cagliari on a Norwegian case study, which uses the SPREAD tool to plan active distribution grids. We collaborate with MIT on markets for renewable energy and in the IEA Wind Task.

Typically, several guest scientists, associate professors and international PhD candidates visit us for longer periods throughout the year. However, Covid-19 still affected us in 2022 due to travel restrictions at the beginning of the year. We will work towards resuming these researcher exchanges in 2023.

EU cooperation at CINELDI

CINELDI has collaborated with several EU-projects in 2022. The EU Horizon 2020 (EU-H2020) FlexPlan project involves several work packages of CINELDI (WP1, WP2, WP3, WP6). In November, CINELDI and FlexPlan conducted a joint workshop, facilitated by our partners Energy Norway and SINTEF Energy Research. This workshop ensured that methods and tools developed in Europe, through the FlexPlan project, are made known to Norwegian grid companies.

CINELDI collaborates with EERA (the European Energy Research Alliance), through the projects JP Smartgrids, SP Transmission and SP Energy Storage. WP6 also collaborates with the research project PAN-T-ERA, while WP3 and WP5 collaborate with eNeuron. In addition, CINELDI has collaborated with the ERA-Net project HONOR.

CINELDI also contributed to several applications to the Horizon Europe programme in 2022. The most relevant was HORIZON-CL5-2022-D3-01-08 TALISMAN, Supporting the action of consumers in the energy market and HORIZON-CL5-2021-D5-01-03 DREAM2ZERO Federated Smart EV and V2X Charging for Mass Deployment.

China-Norway cooperation

CINELDI collaborates with the China- Norway projects ChiNo-ZEN and KeyTech-NeVe-ChiNo (the latter via the KSP project FuChar).

Recruitment

PhD candidates and postdoc researchers

This year, four PhD candidates from CINELDI successfully defended their theses. These fresh doctorates are now moving on to relevant research jobs in academia, grid companies and the consulting industry.

CINELDI had 19 active PhD candidates and two postdoc researchers in 2022. Seven of the PhD candidates and one of the postdoc researchers are associated with CINELDI but funded by other sources, including two industrial PhDs. These positions encompass all the disciplines covered by the Centre.

The PhD candidates actively participate in the work packages, and regularly present their results to the partners through webinars and at consortium events.

CINELDI and FME North Wind held a PhD and postdoc seminar on innovation in September and participants from both research centres took part in the two-hour workshop. The event was led by Ida Fuchs, who is the innovation manager for electrification and digitalisation at the Department of Electric Energy at NTNU.

Master's candidates and summer researchers

By the end of 2022, a total of 126 master's students had written their theses on CINELDI projects, with 19 graduating in 2022. The master's students contribute to CINELDI's research, and are potential future researchers and PhD candidates for CINELDI and our industrial partners.

Master's theses are an important contribution to CINELDI, and we are glad to have many excellent master's candidates working on relevant research

topics and making valuable contributions to our work. These candidates bring the up-to-date and specialised knowledge from CINELDI with them into business and academia after completing their studies.

Ensuring that the education and training that students receive from the universities is up to date and relevant is another way that we secure new knowledge on creating the electrical grid of the future. Our scientists at NTNU teach and supervise students, and scientists at SINTEF give guest lectures regularly and they are also contributing as co-supervisors for master's students.

NTNU are currently working to develop the bachelor's degree programme *Electrification and Digitalisation* into a master's degree. Scientists at CINELDI are contributing, and was also involved when the bachelor's degree started in 2021.

Input from a workshop organised together with the FlexPlan project resulted in a lecture on flexible resources in grid planning and operation in NTNU's course *Power System Analysis 2*. This will benefit future Masters of Science graduating from NTNU.

As a recruitment measure, we have decided to continue participating in SINTEF Energy Research's summer scientist programme. This summer, we had several clever summer scientists employed in tasks and with supervisors from CINELDI. The summer jobs give the students both relevant professional competence and an insight into working as a scientist.

What are CINELDI's PhD candidates and master's students doing now?

Thea Øverli

Thea graduated from
NTNU in 2018 with a master's degree
in Energy and Environmental Engineering

Position: Senior engineer in development and analysis at Lede AS. Arranged a conference about grid development in 2022.

Masters' thesis: Consumer flexibility as a resource in the power system of the future

The power system can be utilised much better than today; copper and steel are not always the best solution to a capacity problem. At Lede, I was assigned tasks within flexibility due to my background from CINELDI. My experience from CINELDI opened many doors, and the perspectives I learned from my time there is useful in the more practical work at the power grid company.

What I like about my job is that I can contribute to social development through Norway's most important infrastructure. That is very rewarding, especially in the times we live in now. I have been given an opportunity for development and responsibility at Lede, which I value enormously. What I like best about my job is probably the working environment, which is social and inclusive, young and yet very competent.

CINELDI's work is very relevant for us in Lede. The distribution grid in our area, is full, and there is an enormous demand for new capacity. It will take a long time to expand the current electricity grid. That's why we need to look at other solutions to make better use of the grid.

Sigurd Bjarghov

Sigurd submitted his
PhD dissertation at NTNU in 2022

Position: Research scientist in SINTEF Energy Research and CINELDI

PhD thesis: Designing grid tariffs and local electricity markets for peak demand reduction in distribution grids

My motivation to keep working in research comes from being able to contribute to the green energy transition by providing research insight that help regulators, policymakers and companies make informed choices that support a decarbonised society. Decarbonising the energy sector is complex, and I find it rewarding to provide insight to decisionmakers on the trade-offs between different solutions.

A very useful part of doing a PhD is to acquire knowledge on advanced techniques and methods, and how to apply these to relevant cases and communicate them in a clear manner. In SINTEF, these researcher skills are highly relevant, and you get to continue to grow as a researcher while developing new skills, such as project development and applied research together with industry partners.

The best part of my job? Aside from the fact that I get to work with energy research, I appreciate that I get to be involved in the decision on what research we do and what I work with. This is important for me in the long run. In addition, I work closely with industry partners and incredibly clever colleagues when developing new projects, which I find more rewarding than working as a PhD, where everything is more theory-based and you are a bit disconnected from reality.

Kyrre Kirkbakk Fjær

Kyrre graduated from NTNU in 2021 with a master's degree in Energy and Environmental Engineering

Position: Trainee at SINTEF Energy Research, NVE and BKK.

Master's thesis: Analysis of Dynamic Pricing to utilise Spatial Flexibility in Heavy-Duty Electric Vehicle Charging Demand

When I was a student, I didn't know which direction I wanted to take my career or which types of tasks I found most exciting and interesting. When I discovered the EnergyTrainee position, which enables me to work for three different companies, I knew that this was the position for me.

As a trainee, I get the opportunity to gain first-hand experience from various companies in industry. I get to see different perspectives on how we can solve the challenges that we face in the energy industry every day. Each company has its own tasks and roles to fulfill, so their views on various challenges will be different. From my time at CINELDI, I learned to work in a structured way and to divide large tasks into smaller and more manageable tasks. As a trainee this has been very important when starting in the various companies, as there is a lot of information, new concepts, and tasks to get to know. Modeling and analysis have been my main tasks across the companies I have worked at, which are skills I learned while working on my thesis.

EnergyTrainee partners are also CINELDI partners. So far, seven EnergyTrainees have been stationed at CINELDI.

Communications
- Spreading the knowledge

In 2022, we have placed an extra emphasis on disseminate new knowledge from our results through different channels and activities. Communication is vital for increasing the impact of the research and innovation activities in CINELDI, and communication between partners, key stakeholders and the public is a core activity. Since 2016, our main communication channels have been the CINELDI website and newsletter, the SINTEF blog, and various media outlets. Since 2021, we have also shared centre news and developments via a dedicated LinkedIn page.

CINELDI is now visible in both industry and public discourse. The centre is also recognised as a knowledge hub for research on the power grid, and people in CINELDI are in high demand as presenters at conferences and events. Researchers at the centre also respond to relevant requests from the Norwegian government for knowledge-based advice.

Arendalsuka

We participated in Arendalsuka 2022, the largest political gathering in Norway, where the topic of large-scale electrification of society was strongly represented. Together with SINTEF Energy Research and NTNU, we organised the seminar "How vulnerable is our electrical energy system?". At this event, Centre Director Gerd Kjølle, together with Anngjerd Pleym, Head of Department at NTNU, met six energy politicians for a debate. A factual background from the research was created ahead of the meeting, which contributed to the high quality of the debate. Gerd Kjølle also gave a presentation and participated in another event at Arendalsuka: "The power grid, the forgotten piece in the green shift".

Traditional media

The activity at Arendalsuka resulted in two media contributions. In 2022, several persons in CINELDI participated in the public discussion, and shared knowledge about and insight into different aspects of the energy system, consumption and prices in news articles in both local and leading national newspapers and trade press.

The number of opinion pieces from the centre also increased in 2022, from two to seven. Centre Director Gerd Kjølle's op-ed "In search of a smarter grid" addressed different aspects of the security of supply. She also wrote an op-ed together with the director of the Norwegian Smart Grid Centre, Jun Elin Wiik, on the importance of smart investments in the power grid. NTNU Professor Magnus Korpås and PhD researcher Ingvild Firman Fjellså also contributed to the public discussion through op-eds and interviews.

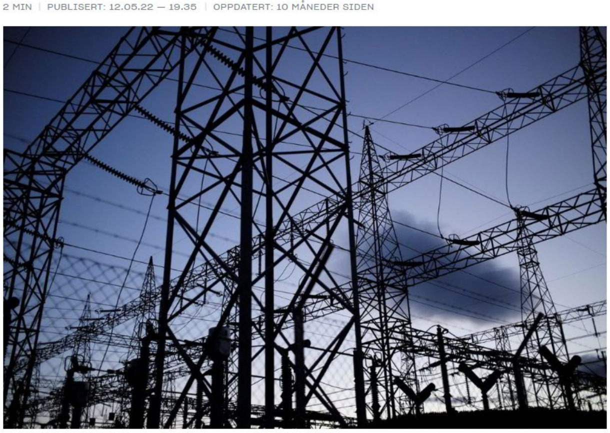
DN

Abonner | Logg inn

Innlegg: Flere må mobiliseres i kampen mot hackerne

Spesialister på cyberrisiko er en knapp ressurs. Derfor bør vi lage et lavterskelverktøy som alle voktere av kritisk infrastruktur kan bruke til å analysere it-sikkerhet.

2 MIN | PUBLISERT: 12.05.22 — 19.35 | OPPDATERT: 10 MÅNEDER SIDEN



Kraftbransjen trenger enkle metoder og sjekklister som ikke-eksperter kan bruke til å analysere cyberrisiko, skriver artikkelforfatterne. (Foto: Gunnar Blöndal)

In March, Gerd Kjølle together with SINTEF colleague Dag Eirik Nordgård, was interviewed in SINTEF's podcast series "Smart forklart" about "How to ensure that the power always reaches your socket?"

Events

People in CINELDI were invited to speak at several conferences, workshops and other events and meetings. Our own "CINELDI days", mentioned on page 13, was open to everyone interested in our field for the first time. This day was a great way for us to communicate results and topics related to the electricity grid of the future. As mentioned earlier, we also organised a workshop series about the energy crisis in Europe and the electricity price crises in Norway in the spring of 2022 together with other actors.

Digital communication activities

Social media

LinkedIn is now our main social media platform – a channel that is effective for communicating science and technology and helping us to reach several target groups – especially people in the industry and other researchers. Together with our Twitter account, we have increased our total social media following from 427 at the end of 2021, to 680 by the end of December 2022. We have also increased our visibility, with 29,560 impressions in social media in 2022, compared to 14,740 in 2021.

From LinkedIn's analytics tool, we can see that our followers are highly relevant to CINELDI, with higher education and utilities (water, electricity, IT etc.) being the two top categories, closely followed by research. We also have followers from industry within renewable energy, hydroelectric power, IT and oil and gas.

Our followers' engagement with our content has also increased, from 428 in 2021 to 898 in 2022. This is proof that our followers find our content meaningful and relevant.

Blog posts

Research scientists and partners in CINELDI are continuously encouraged to write blog posts about their work. In total, 13 people from CINELDI wrote one or more blog posts in 2022, an increase from 8 in 2021. Most of our blog posts summarise project results or scientific publications, and are targeted at different groups, such as private industry or governmental decision makers. Other blog posts are aimed at fellow researchers working with smart grids and related fields.

Website

The primary objective for www.cineldi.no is to provide information about the centre and its research, as well as associated activities and events. The website is regularly updated with research results, new innovations, new pilot projects, and upcoming events.

We started to work on building a knowledge base for our website in 2022. This will be a place where industry, researchers and others can find all our results, sorted according to different topics and presented in a user-friendly way. This work will be published in 2023 and will increase the website's relevance for our different stakeholder groups.

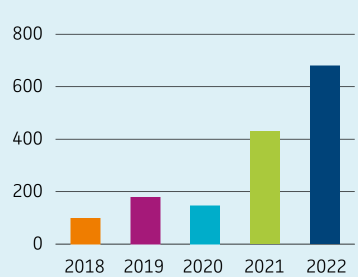
Newsletters

At the end of December, we had 187 subscribers to our newsletter. In 2022, we continued to send regular newsletters, with a total of two sent out over the course of the year. In 2023 we intend to boost the number of newsletters, as we see this as a useful way of reaching key target groups with news and information about upcoming events.

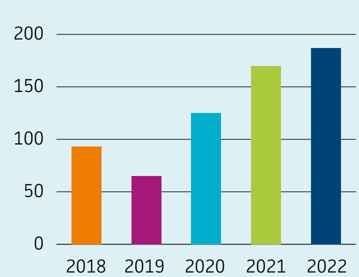
Webinars

Webinars have continued to be a useful activity for CINELDI following the pandemic. This year, we launched an international webinar series in September to reach out to the global research community within the field. Read more about this on page 52.

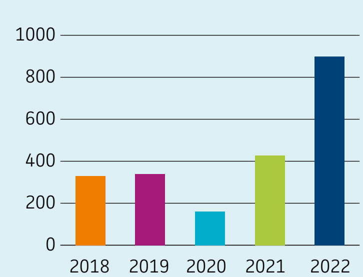
Social media followers



Newsletter followers



Social media engagement



Appendix

Personell

Key researchers

Name	Institution	Main research area
Olav Fosso	NTNU	Centre Management
Sture Holmstrøm	SINTEF Digital	Centre Management
Maren Istad	SINTEF Energi	Centre Management
Gencer Erdogan	SINTEF Digital	Smart grid development and asset management
Inger Anne Tøndel	SINTEF Digital	Smart grid development and asset management
Garau Michele	SINTEF Energi	Smart grid development and asset management
Oddbjørn Gjerde	SINTEF Energi	Smart grid development and asset management
Eivind Solvang	SINTEF Energi	Smart grid development and asset management
Iver Bakken Sperstad	SINTEF Energi	Smart grid development and asset management
Susanne Sandell	SINTEF Energi	Smart grid development and asset management
Bendik Nybakk Torsæter	SINTEF Energi	Smart grid development and asset management
Daniel Bjerkehagen	SINTEF Energi	Smart grid development and asset management
Tom Ivar Pedersen	SINTEF Energi	Smart grid development and asset management
Håkon Toftaker	SINTEF Energi	Smart grid development and asset management
Poul Einar Heegaard	NTNU	Smart grid operation
Basanta Raj Pokhrel	NTNU	Smart grid operation
Geir Mathisen	SINTEF Digital	Smart grid operation
Martin Gilje Jaatun	SINTEF Digital	Smart grid operation
Borgaonkar Ravishankar	SINTEF Digital	Smart grid operation
Lars Flå	SINTEF Digital	Smart grid operation
Merkebu Zenebe Degefa	SINTEF Energi	Smart grid operation
Jonatan Ralf Axel Klemets	SINTEF Energi	Smart grid operation
Kjell Ljøkelsøy	SINTEF Energi	Smart grid operation
Henning Taxt	SINTEF Energi	Smart grid operation
Tesfaye Amare Zerihun	SINTEF Energi	Smart grid operation
Inga Fossum Holt	SINTEF Energi	Smart grid operation
Håkon Sølberg	SINTEF Energi	Smart grid operation
Santiago Sanchez-Acevedo	SINTEF Energi	Smart grid operation
Stian Nessa	SINTEF Energi	Smart grid operation
Jonatan Ralf Axel Klements	SINTEF Energi	Smart grid operation
Rubi Rana	SINTEF Energi	Smart grid operation
Irina Oleinikova	NTNU	Interaction DSO/TSO and flexible resourses
Salman Zaferanlouei	NTNU	Interaction DSO/TSO and flexible resourses

Name	Institution	Main research area
Magnus Korpås	NTNU	Interaction DSO/TSO and flexible resourses
Emil Diamanchev	NTNU	Interaction DSO/TSO and flexible resourses
Kristoffer Nyborg Gregertsen	SINTEF Digital	Interaction DSO/TSO and flexible resourses
Henrik Lundqvist	SINTEF Digital	Interaction DSO/TSO and flexible resourses
Phillip Maree Johannes	SINTEF Digital	Interaction DSO/TSO and flexible resourses
Giancarlo Marafioti	SINTEF Digital	Interaction DSO/TSO and flexible resourses
Hanne Sæle	SINTEF Energi	Interaction DSO/TSO and flexible resourses
Venkatachalam Lakshmanan	SINTEF Energi	Interaction DSO/TSO and flexible resourses
Sigurd Bjarghov	SINTEF Energi	Interaction DSO/TSO and flexible resourses
Kasper Emil Thorvaldsen	SINTEF Energi	Interaction DSO/TSO and flexible resourses
Dung-Bai Yen	NTNU	Smart grid scenarios and transition strategies
Erlend Sandø Kiel	SINTEF Energi	Smart grid scenarios and transition strategies
Gerd Kjølle	SINTEF Energi	Smart grid scenarios and transition strategies
Raymundo Torres-Olguin	SINTEF Energi	Smart grid scenarios and transition strategies
Yasmin B Sheikh-Mohamed	SINTEF Energi	Smart grid scenarios and transition strategies
Julie Helen Evenstuen	SINTEF Energi	Smart grid scenarios and transition strategies
Arnt Ove Eggen	SINTEF Energi	Smart grid scenarios and transition strategies
Sigurd Hofsmo Jakobsen	SINTEF Energi	Smart grid scenarios and transition strategies

Postdoctoral researchers with financial support from the Centre budget

Name	Nationality	Period	Sex M/F	Topic
Mario Blazquez De Paz	Spanish	01.09.2017-29.02.2020	M	Modelling transition strategies towards smart distribution grids
Michele Garau	Italian	11.04.2018-10.04.2020	M	Modelling of Interactions and Interdependencies in Complex Systems of Power Grid and ICT Systems (IE-073-2017)
Ida Marie Henriksen	Norwegian	06.04.2020-01.05.2024	F	The role of intermediaries in demand response service

Postdoctoral researchers working on projects in the centre with financial support from other sources

Name	Funding	Nationality	Period	Sex M/F	Topic
Chendan Li	NTNU - SO	Norway	01/2019 - 01/2021	F	Methods and tools for stability assessment of microgrid systems dominated by Power Electronic converters.
Soumya Das	ROME-project - Indnor	India	02/2020 - 02/2022	M	Integrated methods and tools for planning and operation of Microgrids

PhD Students with financial support from the Centre budget

Name	Nationality	Period	Sex M/F	Topic
Mohammad Ali Abooshabab	Iran	25.08.2017-31.12.2020	M	Distributed and hierarchical dynamic state estimation for smart distribution grids
Fredrik T.B.W Göthner	Norway	14.08.2017-10.12.2020	M	Smart power control in microgrids with modern power converters
Güray Kara	Turkey	01.06.2017-30.11.2020	M	Techno-economic optimization for analysing consumer flexibility and related market structures
Maciej Grebla	Polan	10.11.2019-09.05.2020	M	Power system protection in microgrids
Ingvild Fjellså	Norway	02.03.2017-02.10.2021	F	Understanding mechanisms and incentives for motivating user flexibility
Romina Muka	Albania	18.01.2018-27.02.2021	F	Self-Healing and Autonomous Smart Grid Operation
Kasper Thorvaldsen	Norway	01.09.2018-31.08.2021	M	The value of buildings' energy flexibility in the power market
Fredrik Bakkevig Haugli	Norway	01.09.2017-25.01.2022	M	Distributed and centralized control to support smart grid operation with high quality in a cost-efficient way
Stine Fleischer Myhre	Norway	01.08.2019-31.07.2022	F	Risk and vulnerability in the future intelligent electricity distribution system
Kalpanie Mendis	Sri Lanka	08.01.2018-13.06.2023	F	5G for Low-Latency, Secure, and Dependable Communication Services for Fault Handling in Micro Grids
Outi Pitkänen	Finland	27.04.2020-16.04.2023	F	Integrating consumer (end-user) knowledge in demand-response technology and service design
Emil Dimanchev	Bulgaria	01.08.2020-31.07.2023	M	Utilization of electric vehicle storage flexibility in modern power grids
Natasa Gajic	Serbia	15.05.2021-14.05.2024	F	Methods for assessment of the cyber-physical security of smart grid operations in the presence of large-scale and controllable DER
Dung-Bai Yen	Taiwan	06.09.2021-05.09.2024	M	Trasition pathways for smart distribution grids in view of market designs, regulation and other incentives

PhD students working on projects in the centre with financial support from other sources

Name	Funding	Nationality	Period	Sex M/F	Topic
Salman Zaferanlouei	NTNU	Iran	2016-2020	M	Integration of electric vehicles into power distribution systems
Tesfaye Amare Zerihun	NTNU, IE	Ethiopia	2015-2020	M	Quantitative Modelling of Digital Ecosystems (Case study: smart distribution grid)
Charles Mawutor Adhra	KPN ProSmart	Ghana	2015-2020	M	Communication Networks for Protection Systems in Smart Transmission Grids
Mostafa Barani	RSO-TSO Energi, NTNU Project Number: 81770920	Iran	2018-2021	M	Reliability Studies in Information and Communication Technology (ICT)-dominated Power Systems
Per Aaslid	SINTEF - PhD	Norway	2018-2021	M	Optimal coordination of distributed flexible resources
Matthias Hofmann	Statnett/NFR (Industry PhD)	German	2018-2022	M	Flexible demand as an alternative to investments in the transmission grid
Sjur Føyen	NTNU - SO	Norway	2018-2022	M	Methods and tools for stability assessment of microgrid systems dominated by Power Electronic converters.
Sigurd Bjarghov	NTNU	Norway	2018-2022	M	Consumer-centric electricity market design integration peer-to-peer and flxibility markets
Kjersti Berg	FINE	Norway	2021-2023	F	Integration of Local Energy Communities into the Norwegian Electricity Distribution System
Aurora Flataker	FuChar	Norway	2021-2023	F	Long-term grid planning considering the electricity demand and flexibility potential of electric transport
Sverre Foslie	SINTEF - PhD	Norway	2021-2024	M	Decarbonization of Energy Supply in Industrial Sites through Sector Coupling/ Integrated Energy Systems
Jarand Hole	NæringsPhD NVE-RME	Norway	2022-2026	M	Integration of PV - grid and system challenges

Master degrees

Name	Sex M/F	Period	Topic
Robert Grindborg Karlsen	M	V22	Load modelling for distribution system planning
Håkon Teppan	M	V22	Infrastructure as Code for Smart Grid security lab
Andreas Aadnøy	M	V22	Case Study on the Grid Integration of Electric Vehicles and Solar Power using the CINELDI test grid
Mikal-Andre Tvedt	M	V22	A rolling horizon approach to optimal operation of flexible assets in a residential household
Tesfay Weldemichael Abraha	M	V22	Optimal use of flexible resources at high-power charging stations for a Norwegian distribution grid
Jon Roaldsøy Walderhaug	M	V22	Flexibility markets as a tool to solve grid problems
Tom Erik Øyen	M	V22	Power System Defence and Restoration (working title)
Runar Hillestad	M	V22	Co-simulation framework for local energy communities
Ine Vågane	F	V22	Local flexibility Market-TSO and DSO coordination
Marthe Vågen	F	V22	Baseline Estimation for Flexibility Validation
Simran Jit Kaur Sandhu	F	V22	Baseline Estimation for Flexibility Validation
Eivind Jamesssen	M	V22	Optimal utilization of grid capacity for connection of new renewable power plants
Alvar Øyasæter	M	V22	Scenarios and transition strategies
Anne Marthe ter Woerds Christensen	F	V22	Application of Stochastic Dual Dynamic Programming to evaluate long-term price signals in short-term optimisation of energy use in buildings
Anders Ryssdal	M	V22	Flexibility markets integration to wholesale power markets and grid congestion support
Victor Aasvæer	F	V22	Flexibility markets integration to wholesale power markets and grid congestion support
Citlali Rodriguez del Angel	F	V22	Large-Scale EV flexibility integration in congestion management and intra-day Markets
Xenia Ritzkowsky	F	V22	Large-Scale EV flexibility integration in congestion management and intra-day Markets
William Solberg	M	V22	The utilization of power purchase agreements, granular guarantees of origin, and shared batteries to increase the value of prosumer solar surplus

Statement of Accounts

(All figures in 1000 NOK)

FUNDING	Amount	inkind	Sum
The Research Council	17842		17842
The Host Institution SINTEF Energy Research		705	705
Research Partners			
NTNU		474	474
SINTEF Digital		0	0
Enterprize partners			
DSOs	7749	10365	18114
TSOs	700	121	821
Vendors	300	3449	3749
Member organizations	200	224	424
Authorities	300	34	334
			42463

COSTS	Amount	inkind	Sum
The Host Institution SINTEF Energy Research	17047	705	17752
Research Partners	10044	474	10518
Enterprise partners		14159	14159
Public partners		34	34
sum			42463

Equipment			
Equipmentcosts for partners in 2022			2690

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12. Zaferanlouei, Salman; Lakshmanan, Venkatachalam; Bjarghov, Sigurd; Farahmand, Hossein; Korpås, Magnus. BATTPOWER application: Large-scale integration of EVs in an active distribution grid – A Norwegian case study. Electric power systems research 2022 ;Volum 209. ENERGISINT NTNU
13. Zerihun, Tesfaye Amare; Treider, Thomas; Taxt, Henning; Nordevall, Lars B.; Haugan, Thomas Sagvold. Two novel current-based methods for locating earth faults in unearthed ring operating MV networks. Electric power systems research 2022 ;Volum 213. s. - NTNU ENERGISINT

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2. Berg, Kjersti; Bjarghov, Sigurd Nikolai; Rana, Rubi; Farahmand, Hossein. The impact of degradation on the investment and operation of a community battery for multiple services. I: 2022 18th International Conference on the European Energy Market - EEM. Institute of Electrical and Electronics Engineers (IEEE) 2022 ISBN 978-1-6654-0896-7. NTNU ENERGISINT
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4. Flataker, Aurora; Malmin, Olav Kåre; Hjelkrem, Odd Andre; Rana, Rubi; Korpås, Magnus; Torsæter, Bendik Nybakk. Impact of home- and destination charging on the geographical and temporal distribution of electric vehicle charging load. I: 2022 18th International Conference on the European Energy Market - EEM. Institute of Electrical and Electronics Engineers (IEEE) 2022 ISBN 978-1-6654-0896-7. SINTEF NTNU ENERGISINT
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9. Dimanchev, Emil. Designing climate policy mixes: analytical and energy systems modeling approaches. Division of Physical Resource Theory lunch seminar; 2022-10-25 - 2022-10-25. NTNU
10. Dimanchev, Emil. Designing climate policy mixes: analytical and energy systems modeling approaches. MIT Joint Program Friday Meeting; 2022-01-28 - 2022-01-28. NTNU
11. Dimanchev, Emil. Optimal climate policy under political constraints and uncertainty: A bi-level optimization approach. Division of Physical Resource Theory weekly seminar; 2022-10-26 - 2022-10-26. NTNU
12. Dimanchev, Emil. Optimal climate policy under political constraints and uncertainty: A bi-level optimization approach. 14th Annual Trans-Atlantic Infraday (TAI) Conference; 2022-11-03 - 2022-11-04. NTNU
13. Dimanchev, Emil. Why wait? Modeling the timing of EV charging station investments and the role of policy. European Operations Research Conference; 2022-07-03 - 2022-07-06. NTNU
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19. Henriksen, Ida Marie. Hvordan skape tillit og aksept for automasjon av strømforbruk?. Smartgrid konferansen 2022; 2022-09-13 - 2022-09-14. NTNU
20. Jaatun, Martin Gilje. An introduction to cybersecurity and industrial applications. The International Conferences on Information Systems and Emerging Technologies (ICISET) and International Conference on Data Science, Machine Learning and Artificial Intelligence (DSMLAI); 2022-11-23 - 2022-11-25. SINTEF
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30. Kjølle, Gerd Hovin; Gjerde, Oddbjørn; Sperstad, Iver Bakken; Istad, Maren Kristine. Kan fleksibilitet hjelpe oss å unngå eller utsette nettinvesteringer?. Fagseminar: Kan fleksibilitet bidra til å unngå eller utsette nettinvesteringer?; 2022-03-21. ENERGISINT
31. Kjølle, Gerd Hovin; Pleym, Anngjerd. Hvor sårbart er vårt elektriske energisystem?. Arendalsuka 2022, Hvor sårbart er vårt elektriske energisystem?; 2022-08-17 - 2022-08-17. ENERGISINT NTNU
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36. Korpås, Magnus. Hva påvirker prissettingen framover?. Kraftprisen og betydningen for smartgrids; 2022-04-07 - 2022-04-07. NTNU
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