Norwegian Centre for Environment-friendly Energy Research

CINELDI
Centre for intelligent electricity distribution

Annual report 2023

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

Summary - Highlights from the Centre's activities

CINELDI is an established and visible research centre, both to the industry and to the general public, recognised as a knowledge hub for research on the power grid. We have launched the first version of the knowledge base documenting Centre results. CINELDI experts are in demand as speakers at conferences and events, and the Centre is often approached for expert consultation in relevant inquiries.

During Arendalsuka, the topic of large-scale electrification of society was high on the agenda. CINELDI organised the seminar "The Power to Electrify: Is the Power Grid Ready?" which included a panel discussion among industry leaders and policymakers in the field. Additionally, the Centre's director participated in panels and held presentations at numerous major events, both physical and digital, such as *Nettkonferansen*, for the members of NITO, and the talk show *Nyans*. Research scientists from the Centre have penned several features and op-eds in relevant industry publications such as *Europower* and *Elektroteknikk*, as well as more wide-reaching articles through channels like Aftenposten and *Teknisk Ukeblad*.

In the final years of the Centre, we are focused on showcasing the results outside the consortium. In November 2023, we held an open CINELDI day. We received clear feedback from participants both within and outside the consortium that such information sharing is crucial for the industry and is at the core of developing the future power grid. In November, we also released a popular science video about the role of the electricity grid in the electrification of society.

A report titled "The Energy Crisis in Europe and the Norwegian Electricity Market" was published in 2023, presenting the conclusions from a workshop series held in 2022. The workshops were conducted in collaboration with several other FMEs: NTRANS, ZEN, HighEFF, Include, and HydroCEN. A total of six workshops were held on various topics regarding the energy crisis in Europe, including energy production and consumption, fair distribution and market design, carbon pricing, energy efficiency, and security of supply.

In 2023, CINELDI worked on a joint case concerning security of electricity supply, including reliability of supply, self-healing grids, and flexibility resources. One of the aims of this case is to identify which issues should be prioritised for further research. The results were presented to the consortium at different points, resulting in many valuable inputs on how to proceed on this work.

We initiated three new pilots in 2023. Even though this was CINELDI's next-to-last year, we prioritised these pilots because of their highly relevant topics and the possibility of achieving results quickly. The results from our large-scale pilot "Flexible power grid by dynamic operation" have been presented both internally in CINELDI, through a summer intern's work and at *Nettkonferansen* 2023. The insights from this project will provide valuable information for developing flexible, robust, and smart distribution systems. The fact that the pilot is large-scale, involving multiple grid companies, means that the efforts of each individual company can also benefit the others through mutual learning and inspire other CINELDI partners. Collaboration between DSOs and TSOs is also a crucial element of this pilot.

This year, three CINELDI PhD candidates defended their theses. Our candidates are moving on to relevant research positions in academia, grid companies, and the consulting industry. Like previous years, we also had many excellent master's candidates researching relevant topics and making significant contributions to the field in 2023. They bring updated and specialised knowledge into the business and academia after completing their studies. As a recruitment initiative, we also employed excellent summer interns working on real-world tasks with mentors from CINELDI. Called "summer scientists", these students are hired through SINTEF Energy Research's summer job program. This provides students with both relevant technical expertise and an understanding of what the job of a research scientist entails.

Photo: Falkeblikk/Linja

The Energy Situation in Europe

CINELDI has previously outlined the driving forces and scenarios that will shape the development of the future flexible and intelligent power grid. Driving forces include long-term and profound changes or developments that affect a broad spectrum of areas or industries over an extended period (megatrends), as well as external and grid-related drivers, enablers, and barriers that influence the progression towards the future grid. Our purpose is to enhance understanding of the requirements of the future power grid and to develop sound strategies for transitioning to a flexible and intelligent grid that is also cost-effective and robust. Electrification is a strong driver for the power grid, given the accelerated climate change and the urgent need for measures to utilise existing grids more effectively. The UN's nature agreement to save and preserve global biodiversity has increased the focus on better utilising existing infrastructure, avoiding unnecessary expansion of the power grid, thereby reducing unnecessary intrusion into natural environments.

The energy crisis in Europe, the surge in electricity prices in Norway, and Russia's invasion of Ukraine have highlighted geopolitics as a new, profound, and long-term change that also affects the power grid. Furthermore, both electrification and geopolitical tensions have led to an increased emphasis on the security of the electricity supply, where the power grid plays a central role. The need to develop power grid solutions that help manage electrification while maintaining security of supply is increasing. This has led to activities addressing these aspects being emphasised

and sharpened further throughout the year and in the preparation of the work plans for 2023.

Various driving forces, megatrends, and the energy situation in Europe indicate that the importance of the power grid is increasing in terms of integrating more renewable power generation, increasing resource utilisation, and reducing CO_2 emissions. The power grid is the key to the electrification of industrial processes, transportation, and more. This will require a great need for more grid capacity, which can be addressed through both new investments and a better utilisation of the grid. This is a common challenge in Europe. Research and pilot activities' relevance and necessity within CINELDI are further strengthened by RePowerEU: affordable, secure, and sustainable energy for Europe, which is EU's plan to accelerate Europe's green transition and make the region independent of fossil energy from Russia. This includes increased renewable power generation, increased efficiency in both power and energy, and increased electrification. CINELDI's results may have transfer value to other countries, for example, regarding the use of flexibility resources or with regard to the electrification of transportation.

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. In 2023, she wrote a chapter in the book *Women in Power* about security of electricity supply in the future intelligent and integrated power system.

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.

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.

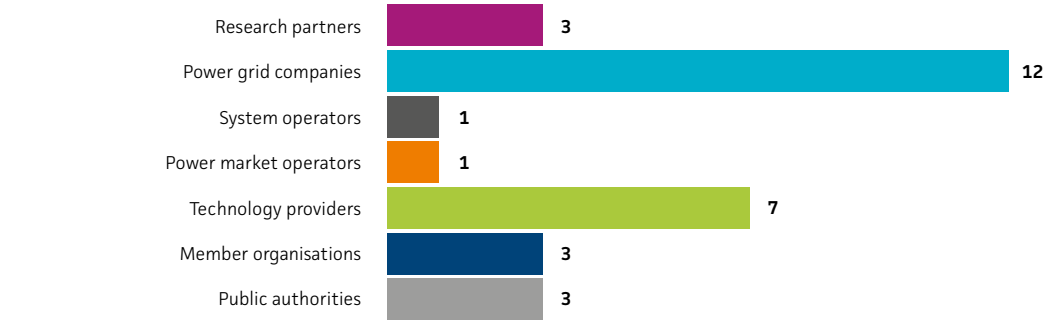
As the project owner of several ongoing projects at Elvia, Kvistad has taken part in many R&D projects within Smart Grids throughout his career. Kvistad also takes part in different fora in the electricity grid sector related to the future grid as well as regulation of the grid companies.

By numbers

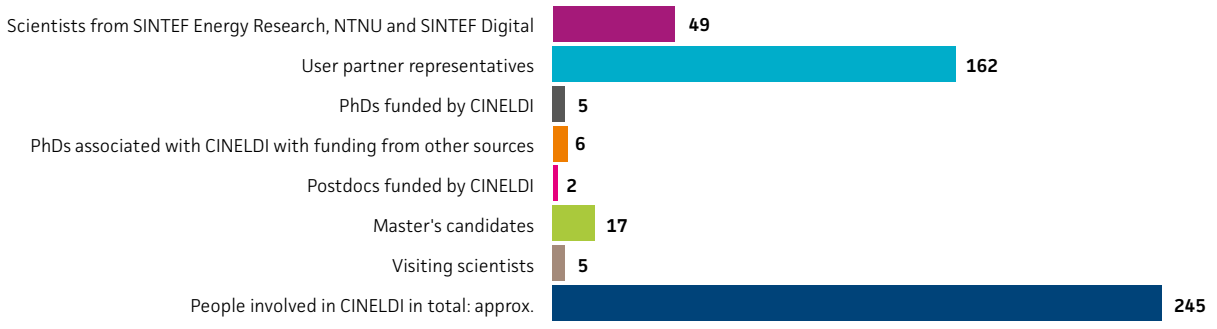
30
partners

373
MNOK

Partners



People 2023



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

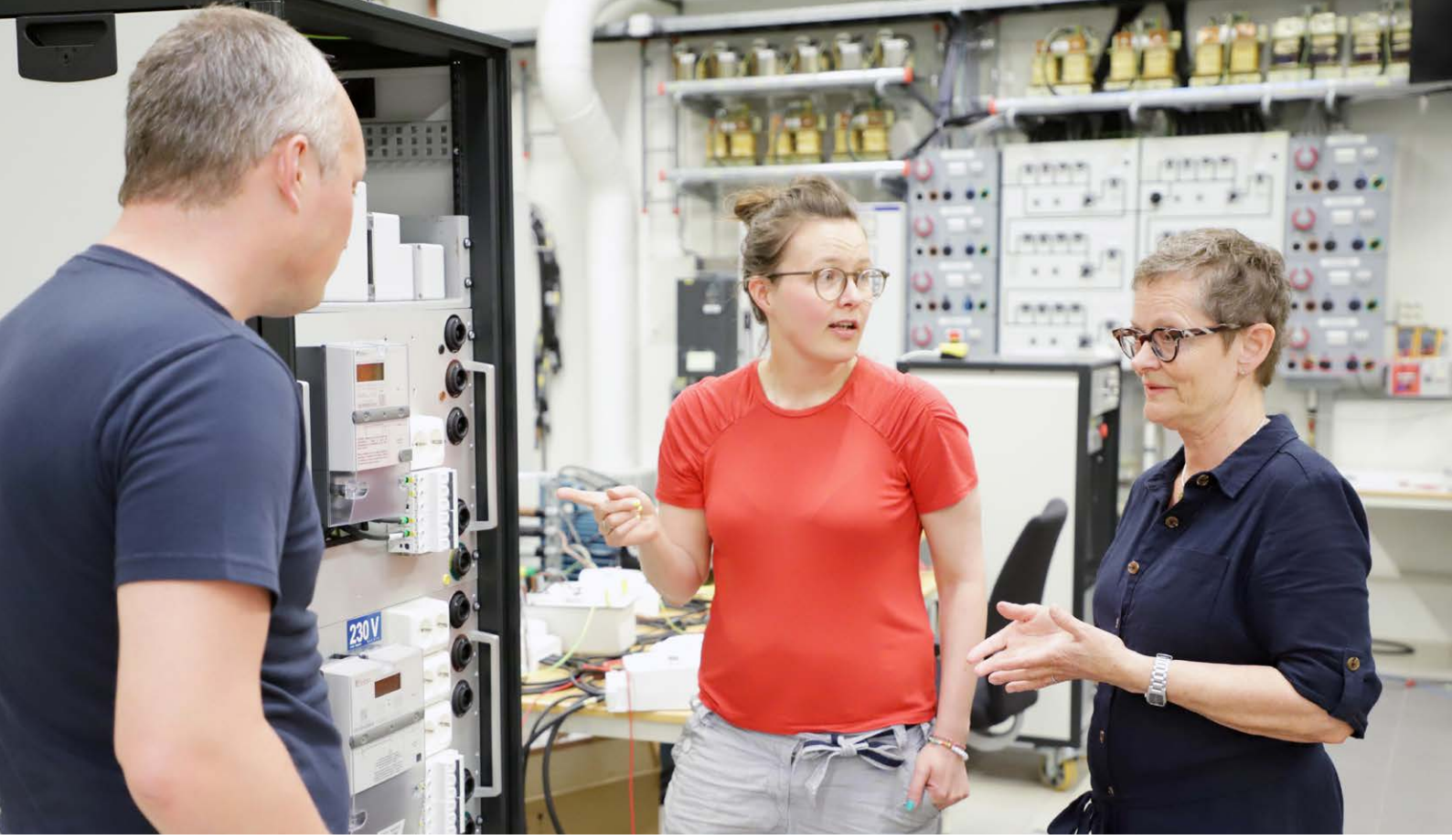
By acting as a national hub for long-term research and innovation within the field of intelligent electricity distribution, we bring together innovative stake-holders with the common task of developing and implementing new technologies, work processes and solutions. The end goal is to develop the electricity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

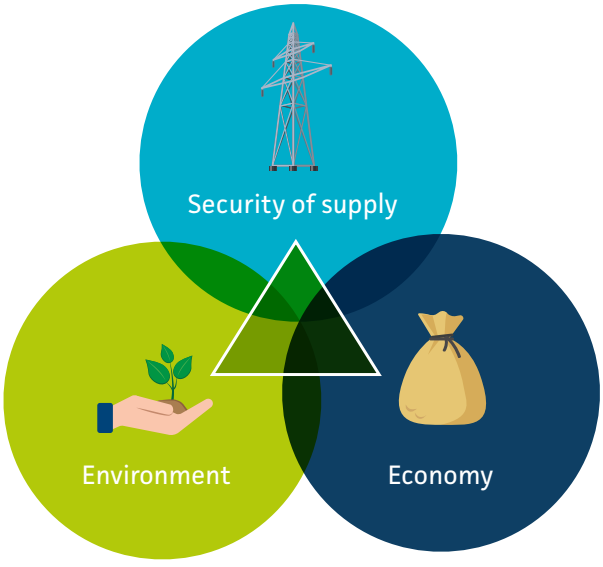
In CINELDI, we are equipped to tackle this challenge with our unique combination of academic resources, computer modelling, and simulation facilities. Through the National Smart Grid Laboratory infrastructure, as well as pilots and demos, we integrate involvement from industry partners, using the physical 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).

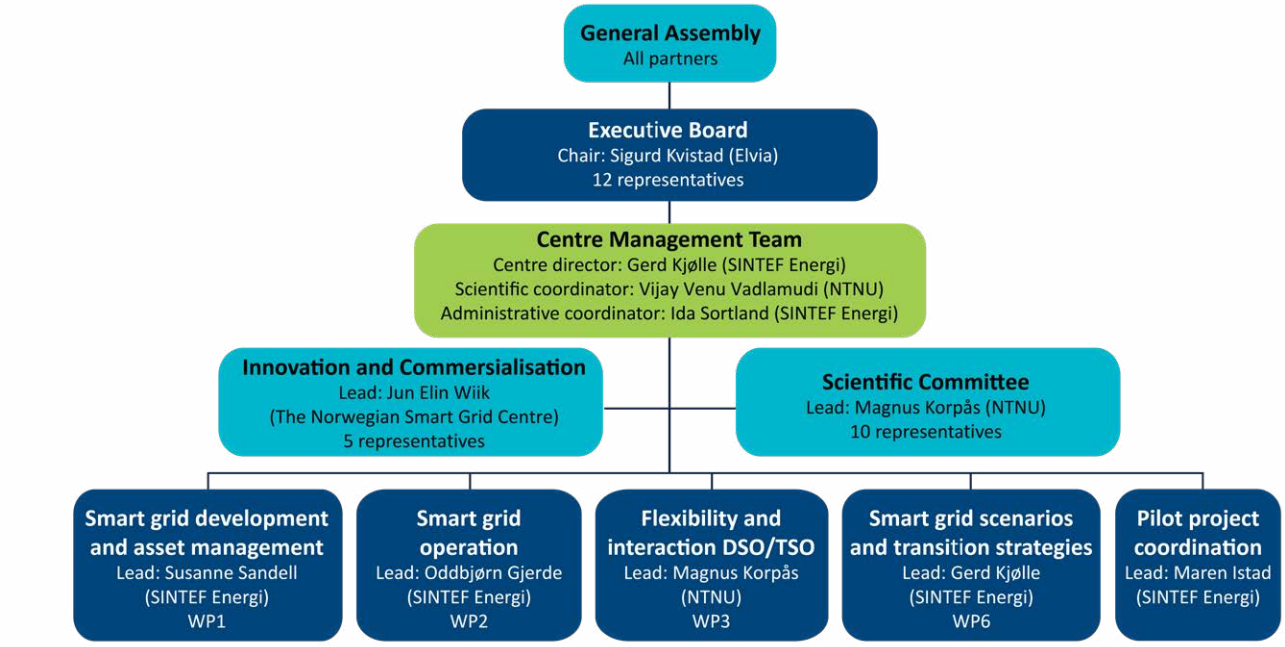
Environment

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 June 2023, the SC met for a two-day workshop in Trondheim to discuss the research topics relevant to CINELDI. Additionally, we held two workshops: the first focused on flexibility and scaling up, exploring barriers and opportunities in different countries, and fostering mutual learning. The second workshop centred on CINELDI's transition strategy and future research collaboration. Each of the members of the SC invited 1 or 2 of their PhD students to attend, resulting in 15 PhD students from institutions in 6 countries joining the workshop.

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.

Front row, from left to right: Mattia Marinelli, Madeleine Gibescu, Gerd Kjølle, Anne Remke.
Back row, from the left: Kari Mäki, Bruce Mork, Magnus Korpås and Gianni Celli.

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, Italian National Agency for New Technologies (ENEA), Italy

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

Photo: Arva

Partners

Research partners

SINTEF Energy Research

Norwegian University of Science and Technology (NTNU)

SINTEF Digital

Power Grid Companies

Glitre Nett / Glitre Energi

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

Cooperation between the Centre's partners

Partners and their impact

Building the smart, flexible, robust grid of tomorrow in a cost-effective way requires a huge effort from all sectors 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.

"Participation in research projects is both important and beneficial for us as a power grid company. In this way, we are able to carry out activities that we would not otherwise have the time and resources to prioritise. Research participation is a crucial aspect of developing a grid company"

– Per-Oddvar Osland, Glitre Nett

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.

Cooperation between partners

One of the keys to success in 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 now together with one TSO and six DSOs – with BKK joining the pilot in 2023. This pilot is working 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 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.

Sector mobility, meeting points and knowledge sharing

At CINELDI, we have experienced less mobility between academia and industry than we originally planned for. The COVID-19 pandemic has been the single largest negative influence in this area for us.

In the period following the pandemic, we managed to gather many and increasingly more participants from partner companies for joint physical meetings, workshops, and events. In these fora we both shared research results and created opportunities for knowledge exchange among the partners. This collaborative effort supports the consortium's common objective: to realise the future power grid. We see a high level of engagement and are pleased to observe that new and younger employees from the user partners continue to engage and participate in the important knowledge and experience platform that CINELDI has become for the industry. Our user partners report that meetings with scientists is a positive aspect of their participation in the Centre.

The mobility between academia and industry in the Centre has consisted of:

- Guest visits from the industry to the National Smart Grid Lab, and workshops associated with the lab at SINTEF Energy Research.
- Partner meetings with visits from research partners to utilities with management and R&D departments.
- Workshops with research institutions, utilities, and technology companies in connection with pilot projects.

CINELDI Workshop was a two-day internal consortium event in April 2023. Among the topics discussed around the tables: How to transfer a research result into an innovation. Another topic was CINELDI's transition strategy for a more flexible and intelligent distribution grid.

The **CINELDI days** were hosted in November – an annual two-day meeting. Like last year, 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 challenges and solutions for the electricity grid. Some of the topics on the first day included: How to integrate solar power into the grid to avoid voltage problems; The increased need for charging infrastructure; and How CINELDI can contribute to a faster connection to the grid.

Webinars are held throughout the year. In these webinars, CINELDI work package leaders, scientists, PhD candidates and partners present ongoing research or research results. In 2023, there were six webinars for the Consortium, where four were open to all interested parties.

Workshops: In 2023, we held three workshops in partnership with other projects: *Cyber security in cyber-physical electricity grids* with SFI NORCICS; *ICT for automation in smart grid and its cybersecurity challenges* with ERIGrid; and a workshop to disseminate the results from the EU project FlexPlan.

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 are linked to other parts of the energy system and of the energy transition, such as other energy carriers, local energy communities and utilisation of flexibility.

We collaborate with FME HighEFF and FME ZEN regarding flexibility in industrial processes, buildings, and local communities respectively. Among other things, this includes the collaboration project ChiNoZEN, under the China-Norway programme. Previously, CINELDI and ZEN had a shared PhD position.

Within the topics of flexibility and energy transition, we have strengthened cooperation with FME NTRANS. In 2023, a report titled "The Energy Crisis in Europe and the Norwegian Electricity Market" was published, presenting the conclusions from a workshop series held in 2022. The workshops were conducted in collaboration between several FMEs: NTRANS, CINELDI, ZEN, HighEFF, Include, and HydroCEN. A total of six workshops were held on various topics regarding the energy crisis in Europe, including energy production and consumption, fair distribution and market design, carbon pricing, energy efficiency, and security of electricity supply.

CINELDI has a collaboration with SFI NORCICS (the Norwegian Centre for Cyber Security in Critical Sectors), where Centre Director Gerd Kjølle has led the work package "Demonstration environments". Under this heading is the research objective: to demonstrate new cyber security technologies, applications, methods, and models in the cyber-physical electricity system of the future. A joint workshop with NORCICS on cyber security was held in March 2023. The purpose of this workshop was to facilitate the exchange of knowledge about cyber security in the future electricity system between scientists and user partners in the two consortia. Approximately 40 people were present at the workshop.

Cooperation on research infrastructure

The National Smart Grid Laboratory

The National Smart Grid Laboratory (NSGL) 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.

Sokratis Katsikas, centre director at NORCICS, and Gerd Kjølle, centre director at CINELDI.

"We want to create a space for mutual learning and exchange of experiences, and to facilitate for discussions on possibilities for cooperation"

- Gerd Kjølle

Collaboration with catapults

The power grid company Fagne is a user partner of CINELDI, and they are involved in establishing the Sustainable Energy Norwegian Catapult Centre. Both this Centre and Fagne are partners in NextGrid. This Green Platform project kicked off in 2023 and is a spin-off project that builds on results from CINELDI.

Living labs

In addition to the NSGL and to computer modelling and simulation facilities, we also make use of the physical grid owned by the distribution system operators (DSOs) and the transmission system operator (TSO) as living labs to test new solutions in the grid.

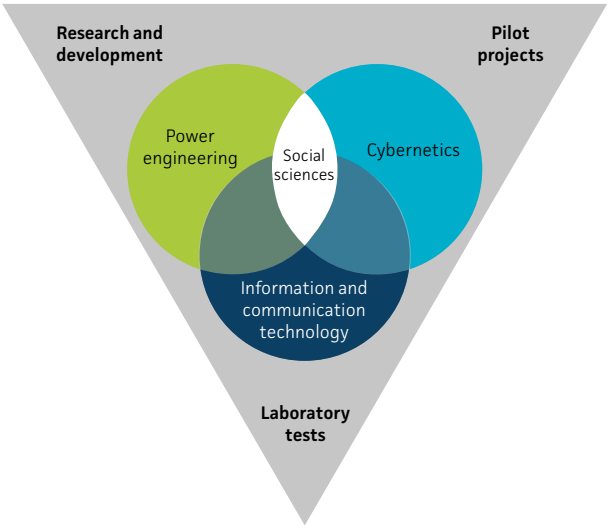
Santiago Sanchez-Acevado, Research Scientist at SINTEF, led a virtual tour of the National Smart Grid laboratory.

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, intelligent, 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.

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.

Research areas

Smart grid development and asset management

Smart grid operation

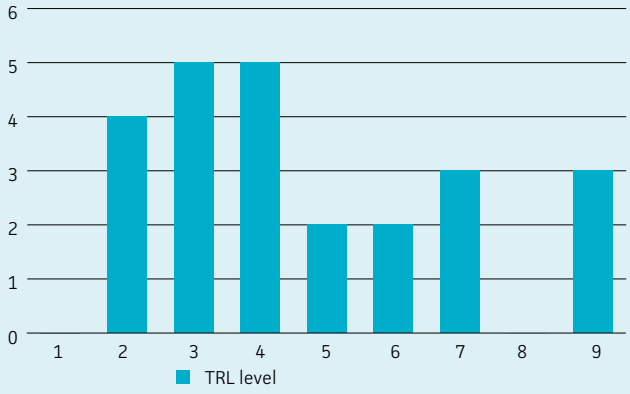
Interaction DSO/TSO

Microgrids/local energy systems

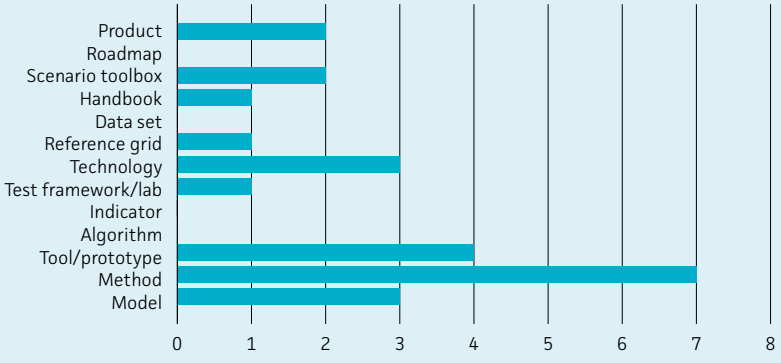
Flexible resources in the power system

Smart grid scenarios and transition strategy

TRL of innovations from CINELDI per Dec 2023



Type of innovations from CINELDI per Dec 2023



Scientific activities and results

To date, CINELDI has produced more than 150 scientific results, and identified 38 innovations. You can find all of these results in the CINELDI Knowledge base.

You can also read about some of our scientific activities and results in 2023 in the following section.

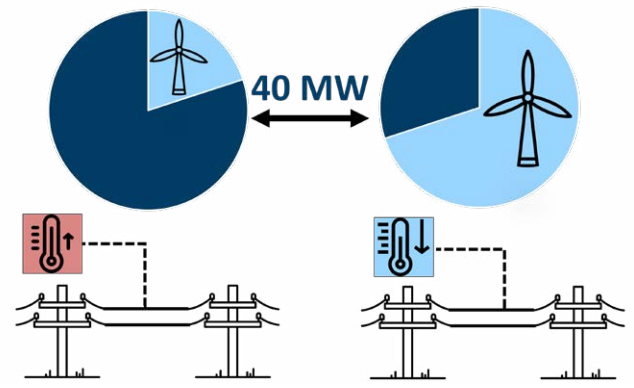
Joint case for security of electricity supply

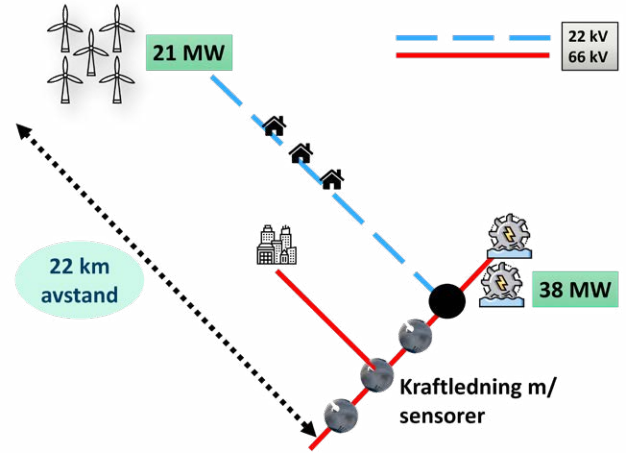
In 2023, CINELDI worked on a joint case concerning security of electricity supply, including reliability of supply, self-healing grids, and flexibility resources. One of the purposes of this case is to identify which issues are most important to prioritise for further research. The results have been presented to the consortium at various stages, resulting in many valuable inputs on how to proceed this work.

Iver Bakken Sperstad presented the joint case at the CINELDI workshop.

Flexibility in the power system through dynamically controlled grids

The large-scale pilot project *Flexible power grid by dynamic operation* was carried out in close collaboration with the utility company Linja and Heimdall Power. In it, research scientists explored how we can better utilise existing grid infrastructure by leveraging the cooling effect that occurs during high wind speeds.





Through an analysis of real data from a grid area at Linja, the power grid company gained important insights for safer operation of the power line associated with the wind farm. The data used in this analysis was production data from a wind farm connected to a power line; static limits on the power line; data from sensors on the power line; and weather data from a nearby weather station.

Results have been shared with the power grid companies who are CINELDI partners. The continuation of this research work is expected to significantly contribute to the accelerated integration of wind power into the grid.

Challenges of TSO-DSO Voltage Regulation

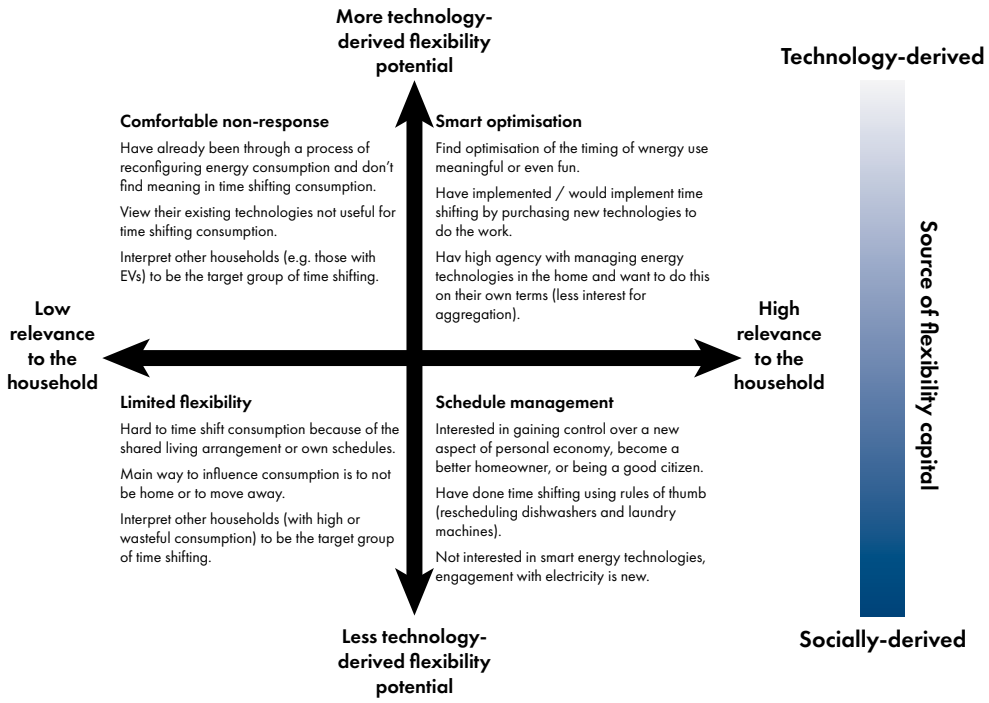
Integration of renewable resources such as solar and wind creates some challenges. These distributed energy resources (DER), makes operational practices such as voltage regulation and congestion management more challenging. Solar and wind energy are characterised by their highly variable generations, inducing new dynamics in the power system. A large amount of DERs may increase transmission grid voltages due to reverse power flow.

To address these challenges, more ancillary services are needed for the transmission system. This will increase the need for operational coordination between transmission and distribution system operators (TSO and DSO).

To study TSO-DSO operational coordination, a realistic cyber-physical test system has been established at CINELDI and the data exchange required for the near-real-time operational coordination was investigated for a reactive power management use case. A realistic inter-control centre communications protocol is implemented in a laboratory environment. Here a physical grid is simulated in a real-time simulator while optimal set-points are communicated from the control centres to simulate assets being communicated through the IEC standard 60870-5-104. In addition, the sufficiency of the common information model (CIM) and common grid model exchange standard (CGMES) has been evaluated for TSO-DSO grid data exchange.

The results from the cyber-physical test setup show that there is a significant difference in the optimal reactive power exchange depending on the level of information exchange. The TSO getting access to a detailed DSO grid model results in lower electrical losses in the system, bringing us to the conclusion that there is clear value to exchanging more detailed grid models. Such data can be difficult to prepare, exchange, and compute, however. The results also show that simplified equivalent models can be acceptable if they are properly tailored to the specific use case. The experiences from the CIM implementation with the CGMES profile are found to be sufficient for such operational data exchange.

Results presented in *IEEE Open Journal of the Industrial Electronics Society.*



Shifting patterns – The patterned enactments of flexible electricity consumption in and by households

This article presents data from household perspective to explore policymakers' and innovators' expectation that households' flexibility potential can be unlocked by introducing new technologies and price signals. The analysis is based on interviews with 20 households (conducted in 2021) who smart grid experts had attempted to engage in flexible consumption. The study explored how informants saw their role as flexible consumers, revealing four different approaches to time shifting:

- Smart indifference: No need for further adjustments of energy technologies.
- Smart optimization: Delegating flexibility work to technologies.
- Schedule management: Using rules of thumb for manual flexibility work.
- Limited flexibility: Flexibility work restricted due to living arrangement.

Most informants with high flexibility potential met time shifting with indifference because they had already been through an active phase of reconfiguring their consumption. They perceived the price signals to be directed at EV owners and didn't see time shifting as compatible with the good use of their technologies. The few informants who wished to do smart optimization by buying more technologies saw themselves as the extra-interested exception that most others would not emulate. Conversely, some informants without such previous engagement were time shifting but did this in ways and for reasons that do not conform to dominant smart grid narratives. Finally, some informants saw that time shifting consumption would make their existing energy problems worse.

The results show that people's interpretations of what flexible consumption is about will influence what they make out of price signals and how they see their room for manoeuver. This variation in interpretations needs to be accounted for, instead of seeing as irrelevant overflows of the dominant smart grid logic. Moreover, the findings show that there is no inevitability that advanced energy technologies will be used for time shifting consumption in the way intended.

The article is under review in Energy Research & Social Science

How do we integrate local energy communities into grid planning?

Local energy communities (LECs) offer unique benefits, such as greater sustainability and cost-effectiveness. However, this transformation presents new challenges for grid companies, who must now find innovative ways to integrate these decentralised energy resources into existing infrastructure while ensuring that the grid remains reliable and affordable.

In a paper published in the scientific journal *Sustainable Energy, Grids and Networks*, research scientists from CINELDI and the two spin-off projects FINE and FuChar, tackle a significant gap in the energy sector: bridging academic research and real-world grid planning. Their work presents a more accessible alternative to existing academic methodologies which often rely on complex optimisation models that are impractical for most grid companies. Designed with grid companies in mind, the new method simplifies these complex models without sacrificing effectiveness. The aim is to make the transition to smart grid planning more attainable for industry professionals.

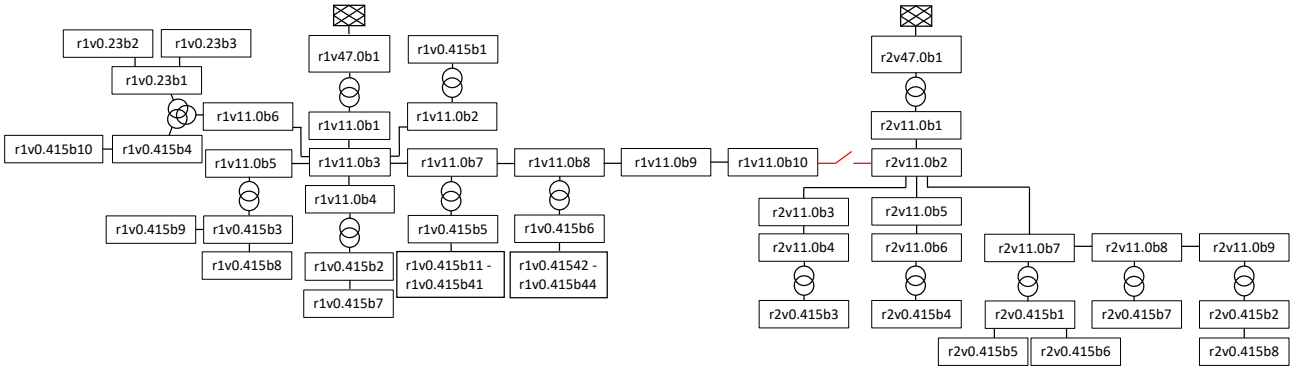
Read more about this new method

Dataset for a Norwegian medium and low voltage power distribution system with industrial loads

Although test grid models are available online, they are typically not representative for real grids. The strength of the reference grid and load data we created is that it describes a real, Norwegian grid with both commercial and industry loads, with hourly load data collected over three years.

At CINELDI, we have converted grid and load data from a real grid to a MATPOWER grid mode, simplified and anonymised. A MV-LV distribution grid and load data set has been established and published openly. It provides useful test data for research and innovation purposes. The dataset can be used to analyse historic load behaviour or predict future behaviour; analyse the need for power system flexibility and reliability of supply; test methods for grid planning; and develop methods and tools for finding remaining grid capacity.

Result presented in Data in Brief



Why publish grid and load data?

In recent years, open research publishing has become increasingly popular – also within the power industry. It's about making research more transparent and easier to validate by providing open access to research data, research code, and any associated software.

Susanne Sandell, Leader of WP 1

Open publishing makes research results and data available to everyone, without a paywall and with few or no restrictions on usage – with a CC BY license, for example. This can range from publishing raw data and software code in open journals and data archives to sharing research results on ResearchGate and LinkedIn. It can provide a range of benefits, both for other scientist in the field and for those choosing to share the data.

For researchers within the field of power system, there are types of data that are very useful to have when validating research results on real datasets. This can include grid datasets that describe infrastructure like power lines, cables, and transformer stations supplying end-users with electricity. It can also include time series showing how much power end-users draw from the grid at any given time – also known as load data – or time series showing how much power wind, solar, or hydropower plants feed into the grid. Data from the grid, load, and production can be combined to create a model of the power system, which we can use to test methods and tools we develop, or to test hypotheses in a relevant environment.

CINELDI has so far published two grid and load datasets: the CINELDI reference grid and a distribution grid in an industrial area.

Two datasets

The CINELDI reference grid is based on a Norwegian radial-operated high-voltage distribution grid with 124 busbars (nodes) and includes scenarios for future load development due to new connections such as fast charging stations and neighbourhoods.

The industrial distribution grid is a medium- and low-voltage distribution grid with 45 connected end-users in an industrial area with a mix of commercial and industrial buildings. The issue in this grid area, which is representative of a challenge faced by many Norwegian grids nowadays, is that several new customers want to connect to the grid, and that existing customers want to significantly increase their load intake. The grid company therefore shared the dataset with us to better understand existing (and estimated future) load levels in their grid, among other reasons. Since this dataset was published openly, it has been used to investigate grid capacity and security of supply in a master's thesis, to assess the need for flexibility in the area, and to determine the value of flexibility in relation to the cost of transformer overload.

Many applications

The dataset can be used to analyse historical loads or forecast future loads, study the loads of individual customers, or test grid planning methodologies or investment optimisation analyses. Due to the reserve supply capability (red line with switch in the figure above), the dataset can also be used to investigate research questions related to security of supply and reserve capacity in the grid.

Norwegian conditions

The international reference grids that are openly available lack some of the typical characteristics of the Norwegian power grid: a large and increasing portion of the grid is underground as cables; the overhead lines are sometimes highly exposed to weather conditions; there are long distances between cities; and the grid is operated radially, perhaps with large load intakes at the end, especially in coastal areas. Power consumption patterns in Norway are different from those in other countries: we have a high degree of electric heating, and the proportion of electric vehicles in Norway is much higher than the European average. Power production in Norway is a mix of controllable and non-controllable renewable energy, primarily hydropower. Therefore, when conducting research and developing solutions for the power system in Norway, it is essential to start with data from the Norwegian grid, load, and production.

Sensitive data

Data collected in connection with a research project may, in some cases, be published openly to be used by other researchers, grid companies, technology providers, innovators, government authorities, and industry associations in the power sector. The data can also be used by universities, to be analysed by bachelor's or master's students as part of their studies.

Grid data may contain power-sensitive information, and the processing of such data is regulated by law. The same applies to load data: how much power you use, and when, is information protected by the Personal Data Act and EU regulations. Detailed production data can also be both power-sensitive and market-sensitive. Therefore, everyone handling sensitive data must have the right contractual framework, legal understanding, and procedures in place. This means that handling such data is time-consuming and somewhat complex. Sensitive data to be published must first go through an anonymisation process: All characteristics indicating station names in the grid or at

measurement points, as well as geographical location, are removed. It may also be relevant to simplify the grid topology to remove characteristics of the grid in an area. This published, non-sensitive data is much easier for potential users to handle and provides equal utility.

Open data for everyone

For research purposes, open publishing of grid and load data can lead to increased transparency and trust in research results. Other scientists in the same field can verify the results and build on them, avoiding the need to spend time acquiring the necessary data themselves. This speeds up the research process and improves resource utilisation. For other stakeholders, making data and code available can increase the research's visibility and impact: When new knowledge is no longer behind a paywall, more people have access to it. This contributes to increased interdisciplinary research. Open access to data also reduces duplication of work since we become more aware of what has been done before.

The anonymised datasets mentioned here are currently being used in other research activities both within and outside of CINELDI. Hopefully, the data will eventually be used by more than just scientists.

The hope is that technology providers will also use open grid and load data. Providers who have easier access to real data and challenges can more easily develop good solutions. Hopefully, this will lead to better software tools being developed more quickly, including by smaller technology providers who do not have the resources to collect data directly from power grid companies. By openly sharing anonymised grid data and load data, we contribute to research, expertise building, and innovation, in addition to fostering a culture of sharing and collaboration in the power industry.

Henning Taxt and Susanne Sandell in the Smartgrid laboratory.

Photo: Yidar Jakobsen - Glitre Nett

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 innovation, 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 CINELDI's transition strategy.

The projects are organised into four priority areas: Sensing and digital monitoring; Application of AMR/ grid data; Fault handling and self-healing; and Flexibility.

CINELDI partners are involved in 19 ongoing pilot projects. These range from testing new technologies, algorithms, and software, to testing new functionality that smart meters offer. Some pilot projects are finalised, and their results have been put into practice. A few innovations have emerged as a result of the pilots, and there is potential for even more in the future.

In 2023, we initiated three new pilot projects. Even though this was CINELDI's next-to-last year, we prioritised these pilots because of their highly relevant topics and the possibility of achieving results quickly.

BKK has gained insight and control over flexible loads in their CINELDI pilot, and they are now able to connect

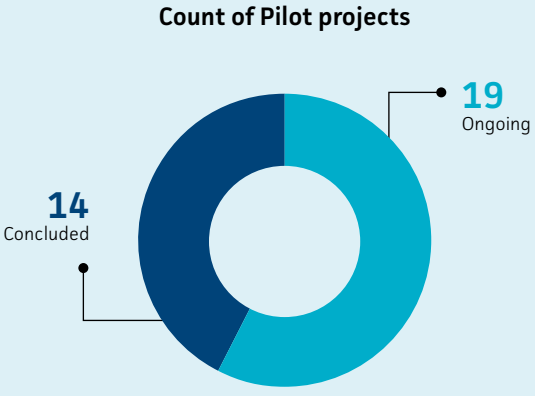
and disconnect 60 of the electric boilers in their area (read more in "Energiteknikk" – in Norwegian). Arva describes their pilot experiences on their website, where they explain how this project has helped them save money (read more on Arva's website – in Norwegian).

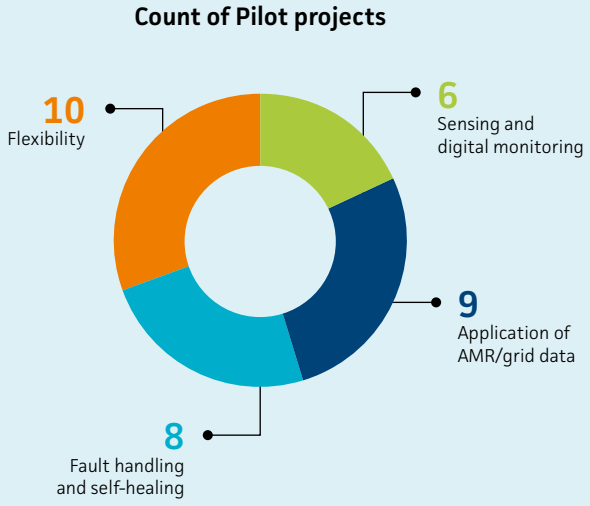
Elvia, a CINELDI partner, has decided to invest heavily in Heimdall Power's technology to gain insight into the capacity of the regional grid (read more on the TV2 website – in Norwegian).

The results from our large-scale pilot "Flexible power grid by dynamic operation" have been presented both internally at CINELDI, through a summer intern's work, and at *Nettkonferansen* 2023.

The fact that the pilot is large-scale, involving multiple grid companies, means that the efforts of each individual company can benefit the others through mutual learning and inspire other CINELDI partners. Collaboration between DSOs and TSOs is also a crucial element of this pilot.

Over the course of 2023, 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

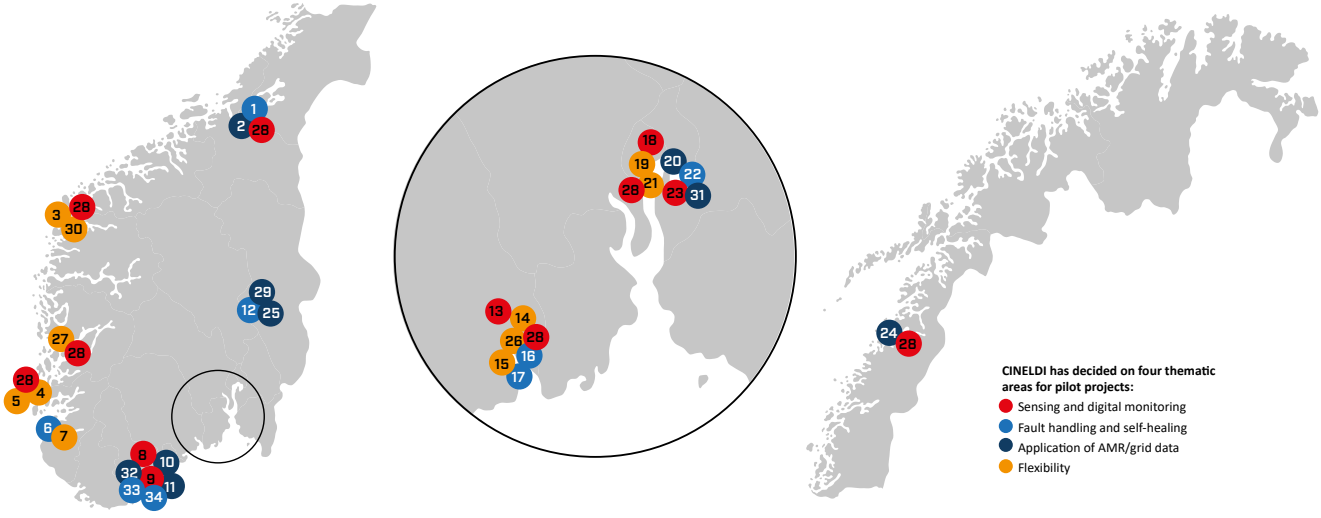
- Added value from Smart meters - Aidon - (2)
- Risk-based distribution network planning - Glitre Nett - (10) *Finalised*
- Predicting peak load in secondary substations - Glitre Nett - (11) *Finalised*
- Probabilistic planning methodology - Norgesnett - (20) *Finalised*
- Development area Molobyen - 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)
- Condition-based maintenance of substations - Glitre Nett - (32) *New*

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)
- AGI - Artificial Grid Intelligence for detecting earth faults in HSP distribution networks - Glitre Nett (33) *New*
- Automated protection and outcome analysis for dynamic grid operation - Glitre Nett (34) *New*

Flexibility

- NODES flexibility platform - Linja - (3) *Finalised*
- Flexibility market - Fagne - (4)
- Utsira: An islanded grid on an island - Fagne - (5)
- Batteries as voltage support- Lnett - (7) *Finalised*
- Optimisation of local balancing with battery - Lede - (14) *Finalised*



- Transition to and from island mode - Lede - (15) *Finalised*
- Active homes - Elvia - (19) *Finalised*
- iFleks - Statnett - (21)
- Fast Frequency Reserve - Lede - (26) *Finalised*
- System for use of flexible resources - BKK - (27)

Sensing and digital monitoring

- Machine learning in grid inspection - Glitre Nett - (8)
- Digital Inspection - Glitre 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)

Winner of CINELDI award

Power grid company Linja and their Head of Technology Division Sven Arild Kjerpeset are the 5th recipients of the annual CINELDI award.

Sven Arild is technology-focused, creative, engaged, and constructive, and a catalyst for development. He has been faithfully present during the CINELDI period, making many valuable contributions in various areas.

Linja also received the award because they are an innovative power grid company in growth. They are a guide and a good role model as a partner in an FME. Throughout the entire centre period, Linja has been an active user partner in various fora, including participation in pilot projects. They entered CINELDI with the intention of improving their use of new technology. They have managed to take advantage of being a partner in a large research centre like CINELDI and have also shown on several occasions their willingness to share their own data and results.

Innovation

In 2023, innovation work has focused on following up on and collaborating in CINELDI's pilot projects, making the results available through the website, and working on the transition strategy.

At the end of 2023, CINELDI had more than 150 scientific results. We have also identified 38 innovations so far. In 2023, we prioritised making fact sheets for innovations on our website that previously lacked this information, resulting in five new fact sheets, four of which were from pilot projects.

An innovation is something *new*, that can be *useful* and *utilised* for value creation. 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 and through new research projects, both national and international, that support 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.

Over the past two years, we have seen a clear maturation of the industry, especially among the power grid companies and Statnett. During this time, they have significantly increased their readiness to use research results and, crucially, to engage with the collaborative platform built by the FME consortium. The potential for collaboration between companies facing the same challenges and demands for innovation is significant. An example of this is sharing experiences with different methods of protection, such as choosing between self-healing networks versus intensified monitoring via sensors. Smaller power grid companies in particular stand to benefit significantly from leveraging the experiences and pilot project outcomes of their larger counterparts within CINELDI. Code developed by one power grid company to integrate data into their control centre, for example, can benefit other power grid companies greatly when shared within CINELDI.

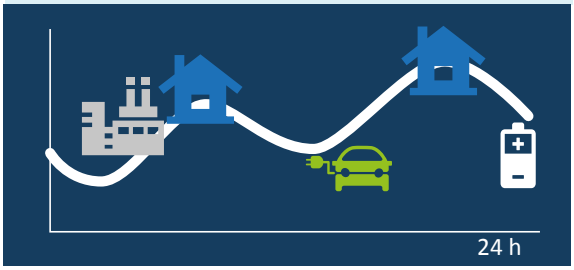
CINELDI's innovations*

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

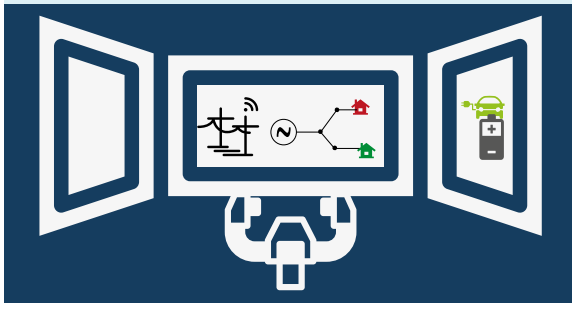


Simulation tool for reliability assessment of modern distribution systems – RELSAD

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

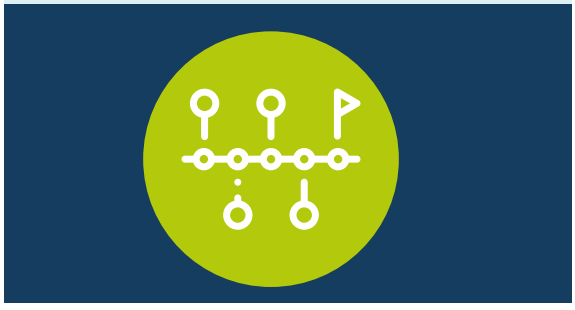


Scenarios for the future electricity distribution grid
To better understand the complexity of the future distribution grid, we identified and structured the driving forces for distribution system innovation. Based on these driving forces, we developed a repository of about 100 mini scenarios.

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

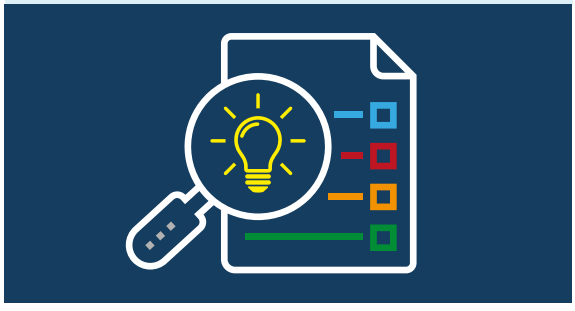
TRL: 3
Target group
- DSOs/TSOs
- Technology providers
- Member organisations
- Market operators
- Researchers and consultants
- Educators



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

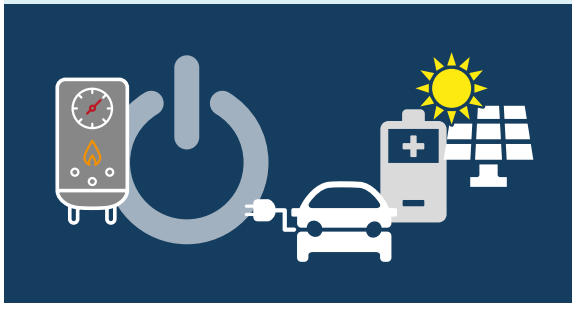


Comprehensive classifications and characterizations of flexible resources

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.

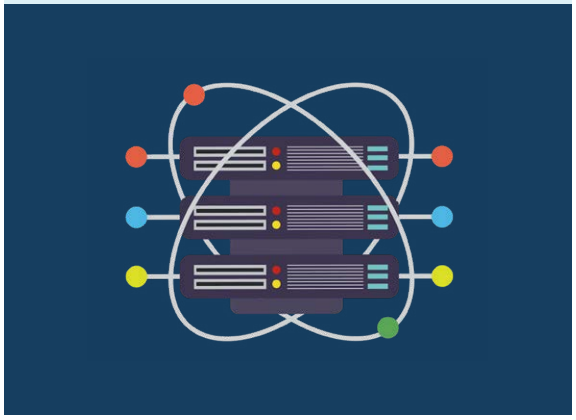
We have developed a new method that provides an easy-to-understand risk picture. The method will improve our understanding of the effects of power grid digitalisation on cybersecurity, and provide decision support for managing reliability of power supply and cybersecurity. This in turn improves the security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

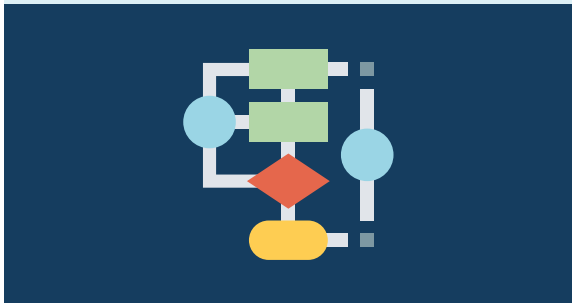
Power system state estimators play a critical role in modern power grids. However, state estimation cannot be easily achieved in smart grids. Therefore, we have developed a simultaneous input and state estimation method (SISE) to estimate the states of a partially known system with system-wide unknown 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

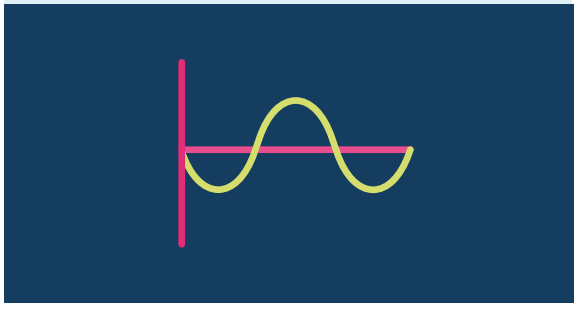
Synchronisation in island electrical grids dominated by power electronics is a challenge due to the absence of a grid reference to follow, lack of inertia sources and the usual lack of communication among the units. A new technique for synchronisation of Voltage Source Converters in microgrids has been 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)

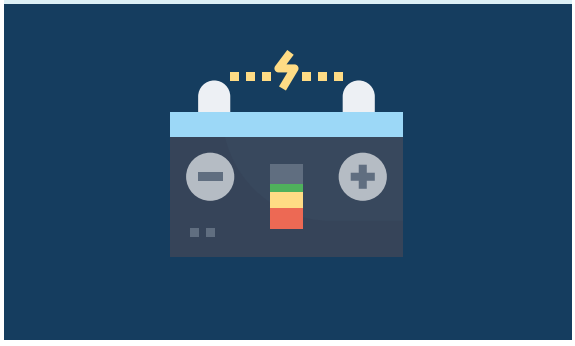
Energy storage and flexible demand makes AC OPF computations very challenging to solve, and computation time is an issue when using commercial or free optimisation solvers. Our solution is to derive a tailor-made optimisation solver for the problem, utilising the structure of the underlying mathematical 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

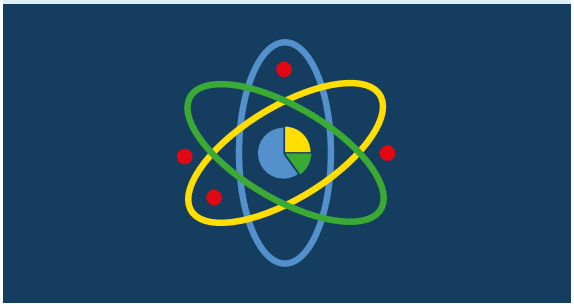
Modelling flexibility can be a difficult task, especially when it involves the considerations of user habits. Appliances such as dishwashers, washing machines and tumble dryers are sources of flexibility, as the frequency of use and the selected program during operation can vary greatly. We have developed 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

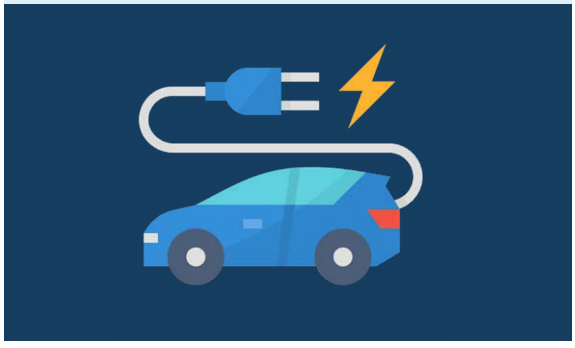
Charging electric cars in an area can cause major power surges both locally and in the grid. A system incorporating POWER SHARE means that power for charging can be regulated dynamically, based either on a maximum value for the respective circuit or on input signals that regulate the maximum value for 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



Reference MV distribution grid data sets

A reference data set for a representative Norwegian radial, medium voltage (MV) electricity distribution grid operated at 22 kV is established: the CINELDI MV reference system (or grid). Grid data from a real MV distribution grid are anonymised and adapted to establish reference grid data representative for Norwegian distribution grids, including topological data, load profiles, new types of loads, reliability data, and standardised component data.

FACTS

TRL: 5

Target group:

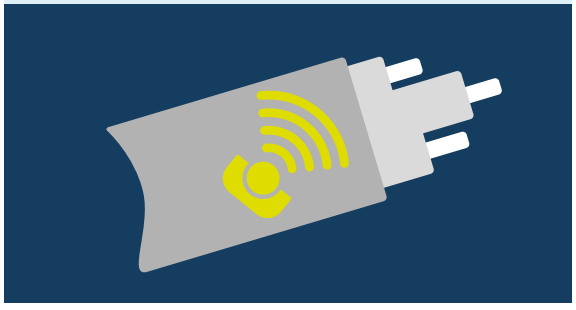
- DSOs/TSOs
- Technology provider
- Member organisation
- Market operator
- Research/Consultancy
- Teaching

Cable monitoring testing (pilot project)
The aim of this pilot project was to test Smart Cable Guard (SCG), which can detect partial discharges in MV cables (paper insulated and XLPE). Two use cases were tested:

1. Operation: Detection and localisation of faults to reduce the outage time.
2. Grid planning/maintenance: Condition monitoring of the cables. This will potentially enable better reinvestment strategies for managing the existing cables.

FACTS

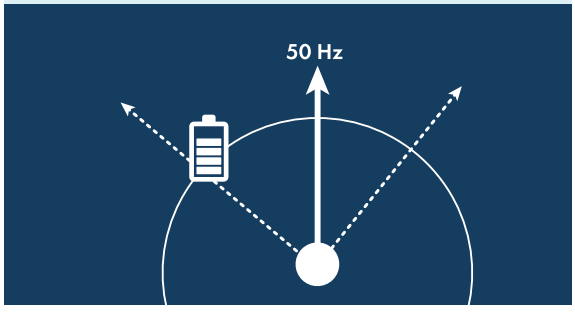
TRL: 8-9 (technology level),
6-7 (system integration level)
Target group
- Control room, fault recovery team
- Maintenance, grid planning



Fast frequency reserve (pilot project)
In this pilot project, a battery energy storage system (BESS) was tested to identify its capability to perform fast frequency response (FFR) service. The main challenge was to fulfil technical requirements related to frequency response, and develop related procedures to plan, manage, activate, and deliver FFR service. The battery energy storage system has a capacity of 1 MW and is installed at Skagerak Arena football stadium in Skien, Norway. The pilot project was carried out from May to October 2021. According to the requirements, the battery energy storage system should be activated within 1.0 second, at 49.6 Hz, and for a duration of 30 seconds.

FACTS

TRL: 9
Target group
- Owners / operators of batteries



Transition to and from island mode (pilot project)
The 1 MW battery energy storage system (BESS) at Skagerak EnergiLab is designed to supply the station lights and other connected consumers during football matches in case of a power outage. Hence, the stadium can become a small microgrid, entering island mode. In the pilot project, the transition to and from island mode – both planned and unplanned – transition was studied with emphasis on electrical phenomena in the transition phase. Attention was given to determining whether or not the regulation on quality of supply was violated during the transition.

FACTS

TRL: 9
Target group
- Owners and operators of BESS
- Owners and users of diesel aggregate as backup solutions in case of power outages.

Active homes (pilot project)
Smart grid is also about the end user, i.e. the consumer, and their electricity consumption habits. The aim of this pilot project was to investigate how different tariffs and communication messages can influence end-user-flexibility and reduce peak loads. Building on the insights from this pilot project, Elvia has introduced new tariffs. These innovations will impact tariffs today and in the future, not only at Elvia but also for other Distribution System Operators (DSOs).

FACTS

TRL: 7
Target groups:
- DSOs/TSOs

Spin-off projects

CINELDI aims to contribute to new national and international projects that contribute to the Centre's goals, along the entire R&D-innovation chain. Particular attention is given to Horizon Europe projects at higher TRL levels (5-9). CINELDI contributes to discussions and provides input for new project ideas where it identifies new needs:

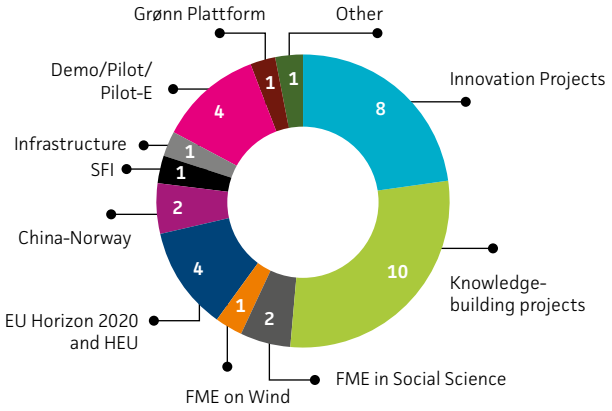
- Knowledge-building projects (KSP) where there is a need for new knowledge not previously covered by CINELDI
- Innovation projects (IPN) in the form of spin-offs or within related topics that CINELDI can collaborate on
- EU projects where there are calls and opportunities that align with CINELDI themes
- Demo/pilot projects (e.g., Pilot-E) run by other entities such as Enova
- Green Platform projects

In 2023, many of the CINELDI partners, together with other actors, worked on an application for a new FME centre as a follow up to CINELDI.

Between 2017 and 2023, 71 CINELDI-supported applications were submitted. By the end of 2023, 67 applications had been evaluated and 35 granted; a success rate of 52.2 per cent.

This shows that on the one hand, CINELDI has contributed to structuring research within the Centre's thematic area, and on the other hand, has facilitated the initiation of projects resulting wholly or partially from the Centre's work.

The number of clarified applications with approvals to which CINELDI has contributed as of November 2023 is distributed by type of project/application in the following figure.



NextGrid, Flex-E and NordKap

The Green Platform project NextGrid was launched in 2023. It is a spin-off of CINELDI and builds on Centre results. The project involves several CINELDI technology partners and three of the grid companies, aiming to prepare the operation centres of Norwegian grid companies for future complex and automated operations.

Other spin-off projects that kicked off in 2023 and were partly based on CINELDI results include the Pilot-E project Flex-E for efficient flexibility aggregation for the commercial market, and the Arctic 2030-project NordKap. The NordKap project is about smart grid capacity for the green transition in Northern Norway. It will contribute to the development of sustainable communities in Northern Norway by innovating and demonstrating how both existing and future power grids can be used more intelligently and efficiently, based on results and insights from CINELDI.

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 act as opponents of PhD dissertations.

In 2023, our research scientists have also actively participated at international conferences such as the *International Conference on Electricity Distributio*n (CIRED 2023), *IEEE Belgrade PowerTech*, and the *International Conference on Smart Energy Systems and Technologies*. One of our research scientists, Sigurd Bjarghov, was guest editor for a special issue of Elsevier Energy titled Future Electricity Tariffs and organised a workshop in relation to this in June.

Several of the Centre's research scientists participate in and lead working groups and study committees in organisations such as CIGRE, ISGAN, IEA, CIRED and ETIP SNET. Examples of such working groups that were active in 2023 include "ISGAN KTP Network Planning and Decision Making under Uncertainties" and CIGRE WG C6.45: "The Impact of Distributed Energy Resources (DER) on the Resilience of Distribution Networks".

In 2023, we continued to build on our collaboration with NREL in the US, focusing on laboratory activities, and with the University of Cagliari on the grid planning environment. We collaborate with MIT on markets for renewable energy and in the IEA Wind Task.

Exchange

This year, we had three outgoing and four incoming visiting PhD students on exchange programs. For the incoming PhD students from UPC (Spain), DTU (Denmark) and the Nagaoka University of Technology (Japan), we organised specific seminars so they could present their work to the scientists in the Centre. The outgoing PhD students went to the University of Helsinki in Finland and the Spanish CITCEA-UPC (Centre of Technological Innovation in Power Electronics and Drives).

EU cooperation at CINELDI

CINELDI has collaborated with several EU-projects in 2023. WP6 collaborates with the research project PAN-T-ERA, while WP3 collaborates with eNeuron. CINELDI also collaborates with EERA (the European Energy Research Alliance), through the JP Smartgrids, SP Transmission and SP Energy Storage programs.

FlexPlan

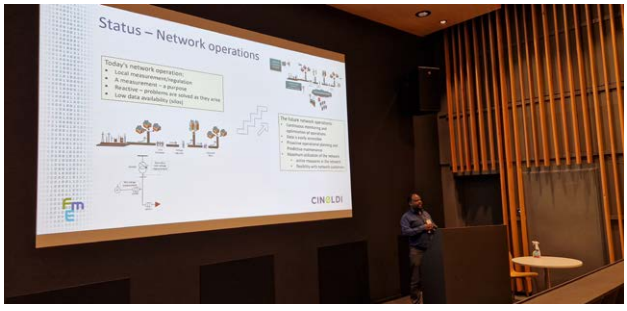
The EU Horizon 2020 FlexPlan project involved several work packages of CINELDI (WP1, WP2, WP3, WP6). The FlexPlan project aimed at establishing a new grid planning methodology. This methodology focuses on the potential integration of new storage and flexibility resources into electricity transmission and distribution grids as an alternative to building new grid elements. In February, CINELDI and FlexPlan conducted a joint workshop to disseminate project results.

ERIGrid 2.0

CINELDI cooperates with ERIGrid 2.0, a European Research Infrastructure supporting Smart Grid and smart energy systems research, technology development, validation and roll out. In January, CINELDI and ERIGrid 2.0 organised a joint workshop in the National Smart Grid Laboratory in Trondheim entitled “ICT for automation in smart grid and its cybersecurity challenges”. The workshop attracted around 30 scientists and professionals from academia, industry, and project partners. It focused on three key areas: automation in smart grids, the application of 5G technology and cybersecurity challenges.

China and India cooperation

CINELDI collaborates with the China-Norway projects ChiNo-ZEN and KeyTech-NeVe-ChiNo (the latter via the KSP project FuChar). In 2023, a delegation from China visited Trondheim. This was the first physical meeting in the project. CINELDI has also collaborated with the India-Norway projects MultiGrid and ROME.



Photos: Tesfaye Amare Zerihun/SINTEF

Recruitment

PhD candidates and postdoc researchers

This year, three PhD candidates from CINELDI successfully defended their theses. Our PhD and master's degree graduates are moving on to relevant research jobs in academia, grid companies and the industry. CINELDI had 19 active PhD candidates and two postdoc researchers in 2023. 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.

PhD candidates are important for a large research centre

This text is based on a blog written by Kasper Emil Thorvaldsen

In June 2023, some of our PhD students met other PhD students from institutions in 6 countries during a workshop together with the Scientific Committee (SC). The SC experts brought along their PhD candidates to this event, providing them with an opportunity to share insights and broaden their professional networks within the scope of the research being undertaken at CINELDI.

Being able to gather PhD candidates is valuable for a centre like CINELDI; they are a crucial component in how we generate new knowledge and innovative solutions. This is a win-win situation; the research in the field expands, and we educate the next generation of research scientists and academics.

Bringing together experienced scientists and PhD candidates creates a dynamic synergy. The research scientists, with their extensive knowledge of current issues and established solutions, contribute a wealth of ideas for methods and topics ripe for further exploration. Meanwhile, PhD candidates are the ones who develop and verify the possibilities and concepts presented by their more experienced counterparts. By doing so, they gain valuable experience that can influence development in the field for many years, before the cycle starts over again when they find themselves on the other side of the table, guiding new PhD candidates.

The expertise and experience acquired by PhD candidates through their academic pursuits are pivotal for driving innovation within their field. Through a PhD, they gain research experience and increase their level of expertise in the field. They will carry this knowledge into the workforce when they graduate and start their careers. This applies to both the private and public sectors.

The analyses and work that PhD candidates undertake in their studies often address specific local issues. Much of the work at CINELDI focuses on the Norwegian power system. But some work also involves extensive collaboration with international actors. Such interactions, especially in forums where multiple international entities participate, are important for developing a more nuanced understanding of relevant issues from a global perspective. At CINELDI's Scientific Committee gathering, work was presented projecting the future of power systems in countries like Italy, the Netherlands, and Denmark. These discussions provided a comprehensive perspective on the diverse challenges present in various international power systems.

Such issues were presented on the second day of the workshop, when PhD candidates had the opportunity to showcase their work to their peers.

Divided into smaller groups, PhD candidates were able to share experiences and insights that could be valuable to others.

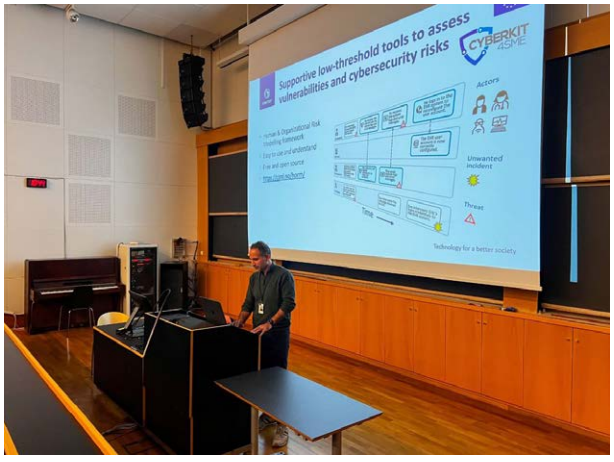
This exercise of presenting one's work to a knowledgeable and diverse group is an important aspect of their academic development. Many insightful questions were raised during the session, not only by people working on similar research but also by individuals offering fresh, alternative perspectives.

Master's candidates and summer scientists

By the end of 2023, a total of 140 master's students had written their theses on CINELDI projects, with 17 graduating in 2023. The master's students contribute to CINELDI's research and are potential future research scientists and PhD candidates for CINELDI and our industrial partners.

Master's theses are an important contribution to CINELDI, and we are proud to have many excellent master's candidates working on relevant research topics, making valuable contributions to our work. These candidates bring CINELDI's up-to-date and specialised knowledge with them into business and academia after completing their studies.

Ensuring that the education and training that students receive from 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, both at NTNU and at the University of Oslo (UiO). They also contribute as co-supervisors for master's students.



Gencer Erdogan held a lecture at UiO about Needs and Challenges Concerning Cyber-risk Assessment in the Cyber-physical Smart Grid – based on work carried out at CINELDI.

NTNU are currently working to develop the bachelor's degree programme Electrification and Digitalisation into a master's degree. Scientists at CINELDI are contributing, much like they were when the bachelor's degree started in 2021.

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

Flexibility in the power system through dynamically controlled grids

Adrian Langmo Pavlak was one of the summer scientists. He worked on a project exploring how we can better utilise existing grid infrastructure with dynamic limits for capacity.

Through an analysis of real data from a grid area at Linja, the power grid company gained important insights for safer operation of the power line associated with the wind farm.

Communications - Sharing the knowledge

Sharing knowledge is important to achieving an electricity grid that is flexible, intelligent, robust and cost-efficient.

In 2023, we continued to place an extra emphasis on disseminating 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, a dedicated LinkedIn page, and various media outlets.

CINELDI now has a prominent presence in the industry and is a regular contributor to the public discourse. The Centre is also recognised as a knowledge hub for research on the power grid, and people in CINELDI are highly demanded as presenters at conferences and events, like *Nettkonferansen* and *Teknologioptimistene*. CINELDI's research has also been presented to the Ministry of Energy, members of NITO (trade union for engineers and technologists) and members of The Norwegian Smartgrid Centre.

Researcher scientists at the Centre also respond to relevant requests from the Norwegian government for knowledge-based advice. CINELDI's research on flexibility and digitalisation was one of the topics being discussed when the Minister of Research and Higher Education visited SINTEF in December.

The CINELDI Knowledge base

CINELDI's Knowledge base (CINELDI Kunnskapsbank), presenting all of the Centre's results, was launched in April 2023. This is an open-access, online knowledge base that summarises all results in various topics and subtopics, based on the six research areas. The results have references to published papers. This knowledge base significantly simplifies the process of discovering new insights about smart grids.

Gathering the results and presenting them in this way contributes to the digitalisation and modernisation of the electricity distribution grid to ensure higher efficiency, flexibility, and resilience. The knowledge base benefits employees at power grid companies, technology providers, market operators, public authorities, scientists and students.

The website has registered a large number of visitors since its launch and is continuously updated with new results.

Implementation of new knowledge

Building the smart, flexible, and robust grid of tomorrow in a cost-effective way requires huge efforts across the entire industry: from public bodies shaping the industry's regulatory framework, to DSOs and TSOs operating the grid within that framework, via other stakeholders in between. CINELDI's results need to be implemented in all these aspects of the industry.

At CINELDI, we have partners that represent all sectors of the industry. This gives us a strong platform to develop the future electricity grid. CINELDI's twelve DSO partners cover about two thirds of Norwegian end users. The national knowledge building carried out by these companies has the potential to significantly impact the power sector. If our partners leverage CINELDI's results to establish a more cost-efficient and flexible grid, they can impact society at large. With our new knowledge base, it is easy to find results that can be of use for all actors working on topics relevant to our power system.

Arendalsuka

In 2023, CINELDI participated in Arendalsuka, the largest political gathering in Norway, for the third time. The topic of large-scale electrification of society was strongly represented. As a part of SINTEF Energy Research's *Energy Tuesday*, CINELDI organised the debate *The power to electrify*: *is the electricity grid ready?* Two panels featured representatives from TSO, DSO, public authorities, the industry, and politicians.

Popular science video

In 2023, we put efforts into creating a video that explains the crucial role of the electricity grid in the electrification of society and reaching climate goals. This video is used in communicating the Centre's work, both through digital channels and at events. Watch the video at www.cineldi.no.

Traditional media

The launch of the knowledge base garnered media attention. Scientists from the Centre penned several articles and op-eds in relevant industry channels in 2023, such as *Europower* and *Elektroteknikk*, as well as more general dissemination in publications like *Aftenposten* and *Teknisk Ukeblad*. Scientists and partners shared knowledge about different aspects of the energy system, like security of electricity supply, batteries, grid capacity, flexibility, and how to integrate local energy communities and fast charging stations into the grid.

In February, Centre Director Gerd Kjølle wrote an opinion piece in trade publication *Europower* with the title "Security of supply is crucial for the success of electrifying Norway". In October, she also talked about security of supply when she appeared on the YouTube talkshow *Nyans*.

Events

Representatives from various CINELDI partner organisations were invited to speak at several conferences, workshops and other events and meetings. Our own "CINELDI days" was also open to the general public this year. The event is a great way for us to communicate results and topics related to the electricity grid of the future.

Digital communication activities

Social media

LinkedIn is 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.

We have focused on sharing engaging and useful content on LinkedIn which has yielded results as we see a positive increase in the number of social media views, reach and engagement. Sharing of content from our knowledge base and our innovations has proven popular on this platform. A news article about Gerd Kjølle's contribution in the book *Women in Power – Research and Development Advances in Electric Power Systems* also got great visibility.

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

Blog posts

Research scientists and partners in CINELDI are continuously encouraged to write blog posts about their work. The Centre had 25 unique bloggers in 2023. 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 research scientists working with smart grids and related fields.

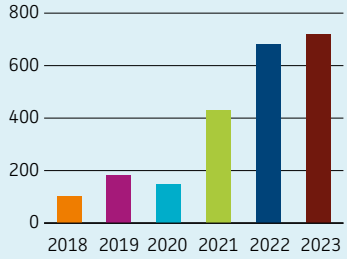
Website

The primary objective of 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. Our newly published Knowledge base increases the website's relevance for our different stakeholder groups.

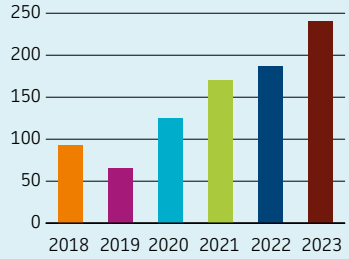
Newsletters

At the end of December, we had 240 subscribers, an increase of 38 from 2022. We continued to send newsletters regularly, with a total of six sent out over the course of the year. We find newsletters a useful way of reaching key target groups with news and information about upcoming events.

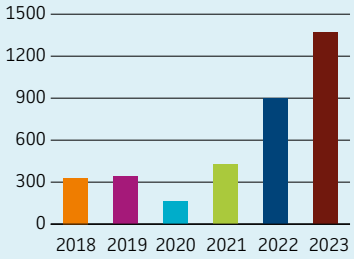
Social media followers



Newsletter followers



Social media engagement



Appendix

Personell

Key Researchers

Name	Institution	Main research area
Gerd Kjølle	SINTEF Energi	Centre Management
Maren Istad	SINTEF Energi	Centre Management
Olav B. Fosso	NTNU	Centre Management
Vijay Venu Vadlamudi	NTNU	Centre Management
Andrei Z Morch	SINTEF Energi	Interaction DSO/TSO and flexible resourses
Fredrik Bakkevig Haugli	SINTEF Digital	Interaction DSO/TSO and flexible resourses
Hanne Sæle	SINTEF Energi	Interaction DSO/TSO and flexible resourses
Kasper Emil Thorvaldsen	SINTEF Energi	Interaction DSO/TSO and flexible resourses
Magnus Korpås	NTNU	Interaction DSO/TSO and flexible resourses
Mariann Merz	SINTEF Digital	Interaction DSO/TSO and flexible resourses
Markus Månum Moen	SINTEF Energi	Interaction DSO/TSO and flexible resourses
Sigurd Bjarghov	SINTEF Energi	Interaction DSO/TSO and flexible resourses
Sture Holmstrøm	SINTEF Digital	Interaction DSO/TSO and flexible resourses
Tom Ivar Pedersen	SINTEF Energi	Interaction DSO/TSO and flexible resourses
Venkatachalam Lakshmanan	SINTEF Energi	Interaction DSO/TSO and flexible resourses
Adrian Langmo Pavlak	SINTEF Energi	Smart grid development and asset management
Eivind Solvang	SINTEF Energi	Smart grid development and asset management
Gencer Erdogan	SINTEF Digital	Smart grid development and asset management
Hallvar Haugdal	SINTEF Energi	Smart grid development and asset management
Oddbjørn Gjerde	SINTEF Energi	Smart grid development and asset management
Sigurd Hofsmo Jakobsen	SINTEF Energi	Smart grid development and asset management
Susanne Sandell	SINTEF Energi	Smart grid development and asset management
Thomas Treider	SINTEF Energi	Smart grid development and asset management
Merkebu Zenebe Degefa	SINTEF Energi	Smart grid operation
Raymundo Torres-Olguin	SINTEF Energi	Smart grid operation
Atle Riise	SINTEF Digital	Smart grid operation
Basanta Raj Pokhrel	NTNU	Smart grid operation
Borgaonkar Ravishankar	SINTEF Digital	Smart grid operation
Fredrik Iversen	SINTEF Energi	Smart grid operation
Geir Mathisen	SINTEF Digital	Smart grid operation
Henning Taxt	SINTEF Energi	Smart grid operation
Henrik Lundqvist	SINTEF Digital	Smart grid operation

Name	Institution	Main research area
Jonatan Ralf Axel Klemets	SINTEF Energi	Smart grid operation
Kjell Ljøkelsøy	SINTEF Energi	Smart grid operation
Lars Flå	SINTEF Digital	Smart grid operation
Martin Gilje Jaatun	SINTEF Digital	Smart grid operation
Poul Einar Heegaard	NTNU	Smart grid operation
Rubi Rana	SINTEF Energi	Smart grid operation
Stephen Dirk Bjørn Wolthusen	NTNU	Smart grid operation
Stian Nessa	SINTEF Energi	Smart grid operation
Tesfaye Amare Zerihun	SINTEF Energi	Smart grid operation
Vahiny Gnanasekaran	SINTEF Digital	Smart grid operation
Arnt Ove Eggen	SINTEF Energi	Smart grid scenarios and transition strategies
Erlend Sandø Kiel	SINTEF Energi	Smart grid scenarios and transition strategies
Ivar Bjerkebæk	SINTEF Energi	Smart grid scenarios and transition strategies
Iver Bakken Sperstad	SINTEF Energi	Smart grid scenarios and transition strategies
Pedro Crespo del Granado	NTNU	Smart grid scenarios and transition strategies
Santiago Sanchez-Acevedo	SINTEF Energi	Smart grid scenarios and transition strategies
Stine Ekrheim	SINTEF Energi	Smart grid scenarios and transition strategies

Visiting Researchers

Name	Afiliation	Nationality	Sex M/F	Duration	Topic
Veronica Anadon Martinez	UPC Barcelon	Spain	F	3 months	Integrasjon av hurtigladeinfrastruktur i strømnettet (nettplanlegging).
Tim Unterluggauer	DTU	Germany	M	3 months	Fleksibel nettilknytning av ladeinfra-struktur (tilknytning med vilkår)
Takumi Yasuda	Nagaoka University of Technology	Japan	M	3 months	Modular EV Charging System for Apartment Buildings
Juan Camilo Oyuela	Universidad Tecnologica de Pereira	Colombia	M	1 month	Control of an energy storage system based on superconducting elements.
Alejandro Hernandez Matheus	UPC Barcelon	Spain	M	3 months	Machine learning and local energy communities

Postdoctoral researchers with financial support from the Centre budget

Name	Nationality	Period	Sex M/F	Topic
Mario Blazques De Paz	Spain	01.09.2017-02.29.2020	M	Modelling transition strategies towards smart distribution grids
Michele Garu (2018-2020)	Italy	04.11.2018-04.10.2020	M	Modelling of Interactions and Interdependencies in Complex Systems of Power Grid and ICT Systems
Ida Marie Henriksen	Norge	06.04.2020-01.05.2024	F	The role of intermediaries in demand response service
Olga Usachova	Ukraina	01.11.2023-31.10.2025	F	Electricity grids as a site of transformative innovation

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	Norwegian	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
Ingvild Fjellså	Norway	02.03.2017-02.10.2021	F	Understanding mechanisms and incentives for motivating user flexibility
Güray Kara	Turkey	01.06.2017-30.11.2020	M	Techno-economic optimization for analysing consumer flexibility and related market structures
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
Romina Muka	Albania	18.01.2018-27.02.2021	F	Self-Healing and Autonomous Smart Grid Operation
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
Kasper Thorvaldsen	Norway	01.09.2018-31.08.2022	M	The value of buildings' energy flexibility in the power market
Stine Fleischer Myhre	Norway	01.08.2019-31.07.2022	F	Risk and vulnerability in the future intelligent electricity distribution system

Name	Nationality	Period	Sex M/F	Topic
Maciej Grebla	Polan	10.11.2019-09.05.2020	M	Power system protection in microgrids
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	15.05.2021-14.05.2025	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
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
Salman Zaferanlouei	NTNU	Iran	2016-2020	M	Integration of electric vehicles into power distribution systems
Sjur Føyen	NTNU - SO	Norwegian	2018-2022	M	Methods and tools for stability assessment of microgrid systems dominated by Power Electronic converters.
Per Aaslid	SINTEF - PhD	Norwegian	2018-2021	M	Optimal coordination of distributed flexible resources
Mostafa Barani	RSO-TSO Energi, NTNU	Iran	2018-2023	M	Reliability Studies in Information and Communication Technology (ICT)-dominated Power Systems
Matthias Hofmann	Statnett/NFR (Industry PhD)	German	2018-2023	M	Flexible demand as an alternative to investments in the transmission grid
Sigurd Bjarghov	NTNU	Norge	2018-2022	M	Consumer-centric electricity market design integration peer-to-peer and flxibility markets
Kjersti Berg	FINE	Norge	2021-2023	F	Integration of Local Energy Communities into the Norwegian Electricity Distribution System
Aurora Flataaker	FuChar	Norge	2021-2023	F	Long-term grid planning considering the electricity demand and flexibility potential of electric transport

Name	Funding	Nationality	Period	Sex M/F	Topic
Sverre Fosslie	SINTEF - PhD	Norwegian	2021-2024	M	Decarbonization of Energy Supply in Industrial Sites through Sector Coupling/ Integrated Energy Systems
Jarand Hole	NVE	Norwegian	2022-2026	M	Integrasjon av solkraft og system/-nettutfordringer

Master degrees

Name	Sex	Period	Topic
Ingvild Eline Olsen	F	2023	Multimarket Services for Stationary Batteries - Considering Activation of Frequency Containment Normal Operation Reserves
Ingrid Rodahl Kvale	F	2023	Prediction of power, energy and hydrogen demand in a zero-emission port
Lars Skjelbred Nygaard	M	2023	Investments in Low-Carbon Power Generation and Energy Storage under Uncertainty
Markus Karlsen Tørnkvist	M	2023	Bidding strategy for the local electricity market participants
Jon Olav Båtbukt	M	2023	Quantification of the value of flexible demand and renewable energy resources in a local energy market.
Ferdinand Lindal	M	2023	Impact of Industrial Size Battery Storage Systems on Electricity Price Distribution
Erlend Vabø	M	2023	Electric water heaters as flexible energy resources in the power grid
Sivasuthan Raja	M	2023	Informatics-based approaches for estimating flexibility potential of electric water heaters
Marius Rasmussen	M	2023	Potential of Hydrogen Technology for Coastal Electrification: Minimizing Distribution Grid Impacts through Flexibility
Sofie Lorentzen	F	2023	Potential of Hydrogen Technology for Coastal Electrification: Minimizing Distribution Grid Impacts through Flexibility
Ola Furuhaug	M	2023	Intelligent elektrisk distribusjon – elbilladere som fleksibilitetsressurs i distribusjonsnett
Karl Fredrik Anker Wirgenes	M	2023	Proposal and Evaluation of a New Short Circuit Protection Algorithm for Active Meshed Distribution Grids
Clemens Martin Muller	M	2023	Physics informed neural networks in radial load flow calculations
Anna Liv Leikanger Aasen	F	2023	Integration of fast-charging stations in the distribution system – Exploring the potential of alternative grid connection agreements
Magnus Rein Hatletveit	M	2023	A Case Study on the Impact of Vehicle-to-Grid on Reliability of Supply in a Norwegian Distribution System
Erlend Waage	M	2023	Smartgrid Transisjonsstrategier
Ingrid Maria Sundfør	F	2022	Flexibility in Distribution Systems through PyDSAL

Statement of Accounts

(All figures in 1000 NOK)

FUNDING	Amount
The Research Council	17583
SINTEF Energy research (host)	632
NTNU	96
SINTEF Digital	0
Enterprise partners	24704
Public partners	401
Total	**43416**

COSTS	
SINTEF Energy Research (host)	19956
NTNU	7166
SINTEF Digital	3677
Enterprise partners	10554
Equipment enterprise partners	2031
Public partners	32
Total	**43416**

COSTS PER WORK PACKAGE	
Centre management, direct cost and common activities	7 751
WP1 Smart grid development and asset management	5 239
WP2 Smart grid operation	10 672
WP3 Flexibility and interaction DSO/TSO	10 806
WP6 Smart grid scenarios and transition strategies	5 053
WP Pilot	1 135
Equipment	2 031
Inkind Research partners	728
Total	**43 416**

Publications

Peer Reviewed Journal Publications

1. **Berg, Kjersti; Rana, Rubi; Farahmand, Hossein.** Quantifying the benefits of shared battery in a DSO-energy community cooperation. *Applied Energy* 2023 ;Volum 343. ENERGISINT NTNU
2. **Bremdal, Bernt Arild; Ilieva, Iliana; Tangrand, Kristoffer Meyer; Dadman, Shayan.** E-Mobility and Batteries—A Business Case for Flexibility in the Arctic Region. *World Electric Vehicle Journal* 2023 ;Volum 14.(3) s. - UiT
3. **Chapaloglou, Spyridon; Abdolmaleki, Babak; Tedeschi, Elisabetta.** Optimal Generation Capacity Allocation and Droop Control Design for Current Sharing in DC Microgrids. *Energies* 2023 ;Volum 16.(12). ENERGISINT NTNU
4. **Degefa, Merkebu Zenebe; Lundkvist, Henrik; Sanchez Acevedo, Santiago; Gregertsen, Kristoffer Nyborg.** Challenges of TSO-DSO Voltage Regulation Under Real-Time Data Exchange Paradigm. *IEEE Open Journal of the Industrial Electronics Society (OJ-IES)* 2023 ;Volum 4. s. 75-84. ENERGISINT SINTEF
5. **Dimanchev, Emil; Fleten, Stein-Erik; MacKenzie, Don; Korpås, Magnus.** Accelerating electric vehicle charging investments: A real options approach to policy design. *Energy Policy* 2023 ;Volum 181. s. - NTNU
6. **Erdogan, Gencer; Halvorsrud, Ragnhild; Boletsis, Costas; Tverdal, Simeon; Pickering, J. Brian.** Cybersecurity Awareness and Capacities of SMEs. *ICISSP* 2023 s. 296-304 SINTEF
7. **Foslie, Sverre Stefanussen; Knudsen, Brage Rugstad; Korpås, Magnus.** Integrated design and operational optimization of energy systems in dairies. *Energy* 2023 ;Volum 281. s. - NTNU ENERGISINT
8. **Foslie, Sverre Stefanussen; Straus, Julian; Knudsen, Brage Rugstad; Korpås, Magnus.** Decarbonizing integrated chlor-alkali and vinyl chloride monomer production: Reducing the cost with industrial flexibility. *Advances in Applied Energy* 2023 ;Volum 12. ENERGISINT NTNU
9. **Hofmann, Matthias; Bjarghov, Sigurd Nikolai; Nessa, Stian.** Norwegian hourly residential electricity demand data with consumer characteristics during the European energy crisis. *Data in Brief* 2023 ;Volum 51. NTNU ENERGISINT
10. **Hofmann, Matthias; Siebenbrunner, Turid.** A rich dataset of hourly residential electricity consumption data and survey answers from the iFlex dynamic pricing experiment. *Data in Brief* 2023 ;Volum 50. NTNU
11. **Klemets, Jonatan Ralf Axel; Degefa, Merkebu Zenebe.** A distributed algorithm for controlling continuous and discrete variables in a radial distribution grid. *IEEE Access* 2023 ;Volum 11. s. 2488-2499. ENERGISINT
12. **Korpås, Magnus; Fosli Flataker, Aurora; Sæle, Hanne; Torsæter, Bendik Nybakk; Lindberg, Karen Byskov; Jiang, Shanshan; Sørensen, Åse Lekang; Botterud, Audun.** Learning From the Norwegian Electric Vehicle Success: An Overview. *IEEE Power and Energy Magazine* 2023 ;Volum 21.(6) s. 18-27. ENERGISINT NTNU SINTEF
13. **Rana, Rubi; Sperstad, Iver Bakken; Torsæter, Bendik Nybakk; Taxt, Henning.** Economic assessment of integrating fast-charging stations and energy communities in grid planning. *Sustainable Energy, Grids and Networks* 2023 ;Volum 35. ENERGISINT
14. **Sandell, Susanne; Bjerkehagen, Daniel; Birkeland, Bjørn; Sperstad, Iver Bakken.** Dataset for a Norwegian medium and low voltage power distribution system with industrial loads. *Data in Brief* 2023 ;Volum 48. ENERGISINT
15. **Sperstad, Iver Bakken; Fosso, Olav Bjarte; Jakobsen, Sigurd Hofsmo; Eggen, Arnt Ove; Evenstuen, Julie Helen; Kjølle, Gerd Hovin.** Reference data set for a Norwegian medium voltage power distribution system. *Data in Brief* 2023 ;Volum 47. NTNU ENERGISINT

16. **Sæle, Hanne; Sperstad, Iver Bakken; Høiem, Kristian Wang; Mathiesen, Vivi.** Understanding barriers to utilising flexibility in operation and planning of the electricity distribution system – Classification frameworks with applications to Norway. *Energy Policy* 2023 ;Volum 180. ENERGISINT
17. **Treider, Thomas; Hoidalen, Hans Kristian.** Estimating distance to transient and restriking earth faults in high-impedance grounded, ring-operated distribution networks using current ratios. *Electric power systems research* 2023 ;Volum 224. s. - NTNU

Peer Reviewed Papers

1. **Degefa, Merkebu Zenebe; Rana, Rubi; Taxt, Henning.** Demonstrating interactions of distribution network and local energy communities operating in hierarchically autonomous control architecture paradigm. I: *27th International Conference on Electricity Distribution - CIRED 2023*. IET Digital Library 2023 ISBN 978-1-83953-855-1. ENERGISINT
2. **Erdogan, Gencer; Sperstad, Iver Bakken; Garau, Michele; Gjerde, Oddbjørn; Tøndel, Inger Anne; Tokas, Shukun; Jaatun, Martin Gilje.** Adapting Cyber-Risk Assessment for the Planning of Cyber-Physical Smart Grids Based on Industrial Needs. I: *Software Technologies : 17th International Conference, ICSOFT 2022, Lisbon, Portugal, July 11–13, 2022, Revised Selected Papers*. Springer 2023 ISBN 978-3-031-37231-5. s. 98-121. SINTEF ENERGISINT
3. **Foslie, Sverre Stefanussen; Straus, Julian; Korpås, Magnus.** Green or blue? Enabling industrial decarbonization and demand response with hydrogen for high temperature process heating. I: *2023 19th International Conference on the European Energy Market - EEM*. IEEE (Institute of Electrical and Electronics Engineers) 2023 ISBN 979-8-3503-1258-4. NTNU ENERGISINT
4. **Kjølle, Gerd Hovin.** Security of Electricity Supply in the Future Intelligent and Integrated Power System. I: *Women in Power : Research and Development Advances in Electric Power Systems*. Springer 2023 ISBN 978-3-031-29724-3. s. 189-207. ENERGISINT
5. **Nessa, Stian; Thorvaldsen, Kasper Emil; Sandell, Susanne; Sæle, Hanne; Istad, Maren Kristine; Abelvik-Engmark, E; Blikø, Marianne.** Decision support for matching flexibility measures to flexibility needs in power system planning. I: *27th International Conference on Electricity Distribution - CIRED 2023*. IET Digital Library 2023 ISBN 978-1-83953-855-1. s. 1788-1792. ENERGISINT
6. **Simonsen, Stig; Grindbakken, Ole Kristian Lindahl; Øyvang, Thomas.** Data driven analytical model optimizing grid capacity utilization. I: *27th International Conference on Electricity Distribution - CIRED 2023*. IET Digital Library 2023 ISBN 978-1-83953-855-1. s. 2591-2595. USN
7. **Sperstad, Iver Bakken; Rana, Rubi; Sandell, Susanne.** Methodology for Evaluating Grid Development Strategies Considering Real Options and Risks. I: *2023 IEEE Belgrade PowerTech*. IEEE (Institute of Electrical and Electronics Engineers) 2023 ISBN 978-1-6654-8778-8. ENERGISINT
8. **Sæle, Hanne; Istad, Maren Kristine; Oland, Signe Marie.** Pilot project: battery energy storage system used for fast frequency reserve. I: *27th International Conference on Electricity Distribution - CIRED 2023*. IET Digital Library 2023 ISBN 978-1-83953-855-1. s. 50-54. ENERGISINT
9. **Thorvaldsen, Kasper Emil; Kiel, Erlend Sandø; Sæle, Hanne.** Investigating the role of flexible electrical appliances in a demand charge grid tariff scenario - a Norwegian case study. I: *27th International Conference on Electricity Distribution - CIRED 2023*. IET Digital Library 2023 ISBN 978-1-83953-855-1. s. 2888-2892 ENERGISINT
10. **Thorvaldsen, Kasper Emil; Lakshmanan, Venkatachalam; Sæle, Hanne.** Analysis of Accuracy of Flexibility Baseline Prediction Methods for Office Building at Different

Measuring Points. I: *2023 International Conference on Smart Energy Systems and Technologies - SEST*. IEEE (Institute of Electrical and Electronics Engineers) 2023 ISBN 979-8-3503-9790-1. ENERGISINT

11. **Tokas, Shukun; Erdogan, Gencer.** A Need for Privacy-Assistive Technology in Notice and Consent Paradigm in IoT. I: *Digital Sovereignty in Cyber Security: New Challenges in Future Vision*. Springer 2023 ISBN 978-3-031-36096-1. s. 35-49. SINTEF
12. **Tokas, Shukun; Erdogan, Gencer; Stølen, Ketil.** Privacy-Aware IoT: State-of-the-Art and Challenges. I: *Proceedings of the 9th International Conference on Information Systems Security and Privacy ICISSP 2023*. SciTePress 2023 ISBN 978-989-758-624-8. s. 450-461. SINTEF
13. **Torres Olguin, Raymundo E.; Sanchez Acevedo, Santiago; Mo, Olve; Garces-Ruiz, Alejandro.** Cyber-Physical Power System Testing platform for Topology Identification in Power Distribution Grids. I: *2023 IEEE Belgrade PowerTech*. IEEE (Institute of Electrical and Electronics Engineers) 2023 ISBN 978-1-6654-8778-8. ENERGISINT
14. **Vrana, Til Kristian; Svendsen, Harald Georg; Korpås, Magnus; Couto, António; Estanqueiro, Ana; Flynn, Damian; Holttinen, Hannele; Härtel, Philipp; Koivisto, Matti; Lantz, Eric; Frew, Bethany.** Improving wind power market value with various aspects of diversification. I: *2023 19th International Conference on the European Energy Market - EEM*. IEEE (Institute of Electrical and Electronics Engineers) 2023 ISBN 979-8-3503-1258-4. ENERGISINT NTNU
15. **Zerihun, Tesfaye Amare; Lundkvist, Henrik; Sanchez Acevedo, Santiago.** Performance Evaluation of IEC 61850 GOOSE Messages over a 5G Network for Protection Coordination in Smart Grid. I: *2023 IEEE International Conference on Energy Technologies for Future Grids (ETFG)*. IEEE conference proceedings 2023 ISBN 978-1-6654-5556-5. s. - SINTEF ENERGISINT

Presentations

1. **Bjarghov, Sigurd Nikolai; Askeland, Magnus; Rana, Rubi; Berg, Kjersti; Taxt, Henning.** Lastflytsimulering av storskala solcelleintegrasjon i distribusjonsnettet. Elsikkerhetskonferansen 2023; 2023-10-31 - 2023-11-01 NTNU ENERGISINT
2. **Bjarghov, Sigurd Nikolai; Askeland, Magnus; Taxt, Henning.** Lokale energisamfunn og koordinerings-mekanismer. Brukermøte spenningskvalitet og EMC 2023; 2023-10-31 - 2023-11-01. ENERGISINT NTNU
3. **Erdogan, Gencer.** Cyber security consequences for security of electricity supply and cyber security considerations in grid planning. CINELDI/NORCICS workshop on cyber security in cyber-physical electricity grids; 2023-02-28 - 2023-03-28. SINTEF
4. **Erdogan, Gencer.** Cybersecurity Awareness and Capacities of SMEs. Course IN5130: Unassailable IT-systems.; 2023-10-06 - 2023-10-06. SINTEF
5. **Erdogan, Gencer.** "Hvilke behov har energisektoren for å vurdere cyber-risiko?". Nordea Kraftseminar 2023; 2023-10-26 - 2023-10-26. SINTEF
6. **Erdogan, Gencer.** Needs and Challenges Concerning Cyber-risk Assessment in the Cyber-physical Smart Grid. Course IN5130: Unassailable IT-systems.; 2023-10-06 - 2023-10-06. SINTEF
7. **Foslie, Sverre Stefanussen; Bjarghov, Sigurd Nikolai; Knudsen, Brage Rugstad; Korpås, Magnus.** Industrial flexibility, sector coupling and wind power production to mitigate power grid capacity limitations. 9th International Conference on Smart Energy Systems; 2023-09-12 - 2023-09-13. NTNU ENERGISINT
8. **Foslie, Sverre Stefanussen; Straus, Julian; Korpås, Magnus.** Green or blue hydrogen? Demand response in industrial high temperature heating. The International Conference on European Energy Markets; 2023-06-06 NTNU ENERGISINT

9. **Heegaard, Poul Einar.** 5G communication services for critical infrastructure operation. ERIGrid/CINELDI Conference 2023; 2023-01-31 - 2023-01-31. NTNU
10. **Kjølle, Gerd Hovin.** Forsyningssikkerhet – muligheter og utfordringer i det grønne skiftet. Fagseminar Smartgrid-senteret; 2023-04-26 - 2023-04-26. ENERGISINT
11. **Kjølle, Gerd Hovin.** Forsyningssikkerhet – muligheter og utfordringer i det grønne skiftet. Faglunsj hos OED; 2023-06-14 - 2023-06-14. ENERGISINT
12. **Kjølle, Gerd Hovin.** How to keep the lights on in the energy transition. NTNU Energy Security in Europe Workshop; 2023-03-24 - 2023-03-24. ENERGISINT
13. **Kjølle, Gerd Hovin.** Hva er de viktigste utviklingstrekk som tegner seg for årene fremover innen energi-distribusjon?. Aidon Pro Days; 2023-05-31 - 2023-05-31 ENERGISINT
14. **Kjølle, Gerd Hovin.** Kraftberedskap og forsynings-sikkerhet. Kraftberedskap og forsyningssikkerhet; 2023-05-23 - 2023-05-23. ENERGISINT
15. **Kjølle, Gerd Hovin.** Kraften til å elektrifisere - er strøm-nettet klart?. Kraften til å elektrifisere - er strømnettet klart?; 2023-08-15 - 2023-08-15. ENERGISINT
16. **Korpås, Magnus.** Om solkraft og annen lokal energi-produksjon. Fagmøte NVE; 2023-09-18 - 2023-09-18 NTNU
17. **Korpås, Magnus; Vrana, Til Kristian.** Addressing Market Issues in Electric Power Systems with Large Amounts of Offshore and Onshore Wind Power. DeepWind 2023; 2023-01-19 - 2023-01-19. NTNU
18. **Pitkänen, Outi Milja Kristiina.** Shifting patterns - Norwegian households' enactments of flexible electricity consumption. Beyond Crises / Beyond Normal Conference; 2023-09-27 - 2023-09-28. NTNU
19. **Sperstad, Iver Bakken; Rana, Rubi; Sandell, Susanne.** Methodology for Evaluating Grid Development Strategies Considering Real Options and Risks. 2023 IEEE Belgrade PowerTech; 2023-06-25 - 2023-06-29. ENERGISINT NTNU
20. **Tokas, Shukun; Erdogan, Gencer; Stølen, Ketil.** Privacy-Aware IoT: State-of-the-Art and Challenges. International Conference on Information Systems Security and Privacy; 2023-02-24. UiO SINTEF
21. **Zerihun, Tesfaye Amare; Lundkvist, Henrik Nils Oskar; Sanchez Acevedo, Santiago.** Performance Evaluation of IEC 61850 GOOSE Messages over a 5G Network for Protection Coordination in Smart Grid. Smartgridcomm 2023; 2023-10-31 - 2023-11-03. SINTEF ENERGISINT

Multimedia Products

1. **Kjølle, Gerd Hovin.** Arendalsuka: Kraften til å elektrifisere – er strømnettet klart?. SINTEF 2023. ENERGISINT
2. **Kjølle, Gerd Hovin.** Strømnettet i elektrifiseringen - FME CINELDI. SINTEF Energi aS 2023. ENERGISINT

Op-eds

1. **Kjølle, Gerd Hovin.** – Forsyningssikkerhet avgjørende for å lykkes med elektrifisering av Norge. *Europower* 2023 ENERGISINT
2. **Kjølle, Gerd Hovin.** In search of a smarter grid. *Norwegian SciTech News* 2023. ENERGISINT

Blogs and Information Material

1. **Erdogan, Gencer; Gjerde, Oddbjørn; Degefa, Merkebu Zenebe; Jaatun, Martin Gilje.** Cybersecurity in the electricity grid. SINTEF ENERGISINT
2. **Foslie, Sverre Stefanussen.** Increasing the pace of decarbonization with industrial flexibility. ENERGISINT
3. **Foslie, Sverre Stefanussen.** Økt tempo i avkarboniseringen av Norge med industriell fleksibilitet. ENERGISINT
4. **Kjølle, Gerd Hovin.** CINELDI-dagen 2023: Strømnettets utfordringer – og løsninger. ENERGISINT

5. **Kjølle, Gerd Hovin.** Cyber security in cyber-physical electricity grids. ENERGISINT
6. **Kjølle, Gerd Hovin.** Forskningsresultater om strømnettet er samlet i en kunnskapsbank. ENERGISINT
7. **Kjølle, Gerd Hovin.** Forskningsresultater om strømnettet samlet i en kunnskapsbank. ENERGISINT
8. **Kjølle, Gerd Hovin.** Forsyningssikkerhet avgjørende for å lykkes med elektrifisering av Norge. ENERGISINT
9. **Kjølle, Gerd Hovin.** Gerd Kjølle vil at flere kvinner velger kraftbransjen. ENERGISINT
10. **Kjølle, Gerd Hovin.** Gerd Kjølle wants more women in the power industry. ENERGISINT
11. **Kjølle, Gerd Hovin.** In search of a smarter grid. ENERGISINT
12. **Kjølle, Gerd Hovin.** Norske referansenett for realistiske problemstillinger i strømnettet. ENERGISINT
13. **Kjølle, Gerd Hovin.** Results for a smarter electricity grid gathered on a single website. ENERGISINT
14. **Kjølle, Gerd Hovin.** Results for a smarter electricity grid gathered on a single website. ENERGISINT
15. **Morch, Andrei Z.** New methodology for planning expansion of the electricity grid. NTNU
16. **Morch, Andrei Z.** Ny metode for å planlegge utvidelse av strømnettet. NTNU
17. **Pedersen, Tom Ivar; Istad, Maren Kristine.** Security of supply in smart grids with interacting digital systems. ENERGISINT
18. **Rana, Rubi.** How do we integrate local energy communities into grid planning?. ENERGISINT
19. **Rana, Rubi.** Hvordan kan nettplanleggingen ta hensyn til lokale energisamfunn?. ENERGISINT
20. **Sandell, Susanne.** Hvorfor publisere nett- og lastdata?. ENERGISINT
21. **Sperstad, Iver Bakken.** Når er straumnettet fullt?. ENERGISINT
22. **Strypet, Hanne.** Flexibility needs to be appreciated!. ENERGISINT
23. **Strypet, Hanne.** Forskningens plass i nettselskapene. NTNU
24. **Sæle, Hanne.** Hva er fleksibilitet og hvordan kan det bidra til nytte i kraftsystemet?. ENERGISINT
25. **Thorvaldsen, Kasper Emil.** PhD-er spiller en viktig rolle i et stort forskningssenter. NTNU
26. **Torsæter, Bendik Nybakk.** Smartere ladepriser er effektiv nødhjelp til strømnettet. ENERGISINT
27. **Torsæter, Bendik Nybakk; Hjelkrem, Odd Andre; Fosli Flataker, Aurora; Korpås, Magnus.** Fast charging stations can be built more quickly with these 3 tips. ENERGISINT NTNU

Media Contributions

1. **Backe, Stian; Bjarghov, Sigurd Nikolai; Thorvaldsen, Kasper Emil.** Slik kan vi få automatisk styring av strømforbruk i nabolag. TU [Fagblad] 2023-03-01 ENERGISINT NTNU
2. **Berg, Kjersti.** – Batterier blir så billig at det å løse alle problemer i nettet blir gammeldags. Europower [Internett] 2023-12-29. NTNU
3. **Kjølle, Gerd Hovin.** AI shows promise for energy systems, but machines still have much to learn. S&P Global [Internett] 2023-03-20. ENERGISINT
4. **Kjølle, Gerd Hovin.** Digitalisert strømnett er en del av løsningen: Forsyningssikkerhet avgjørende for å lykkes med elektrifisering av Norge. elektro247 [Fagblad] 2023-01-30. ENERGISINT
5. **Kjølle, Gerd Hovin.**
   En kunnskapsbank med forsknings-resultater om strømnettet. elektro 247 [Fagblad] 2023-04-24. ENERGISINT
6. **Kjølle, Gerd Hovin.** En kunnskapsbank med forskningsresultater om strømnettet. EnergiAktuelt [Fagblad] 2023-04-24
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CONTACTS:

Centre Director
Gerd Kjølle - Gerd.Kjolle@sintef.no

Administrative Coordinator
Ida Sortland - Ida.Sortland@sintef.no