Norwegian Centre for Environment-friendly Energy Research

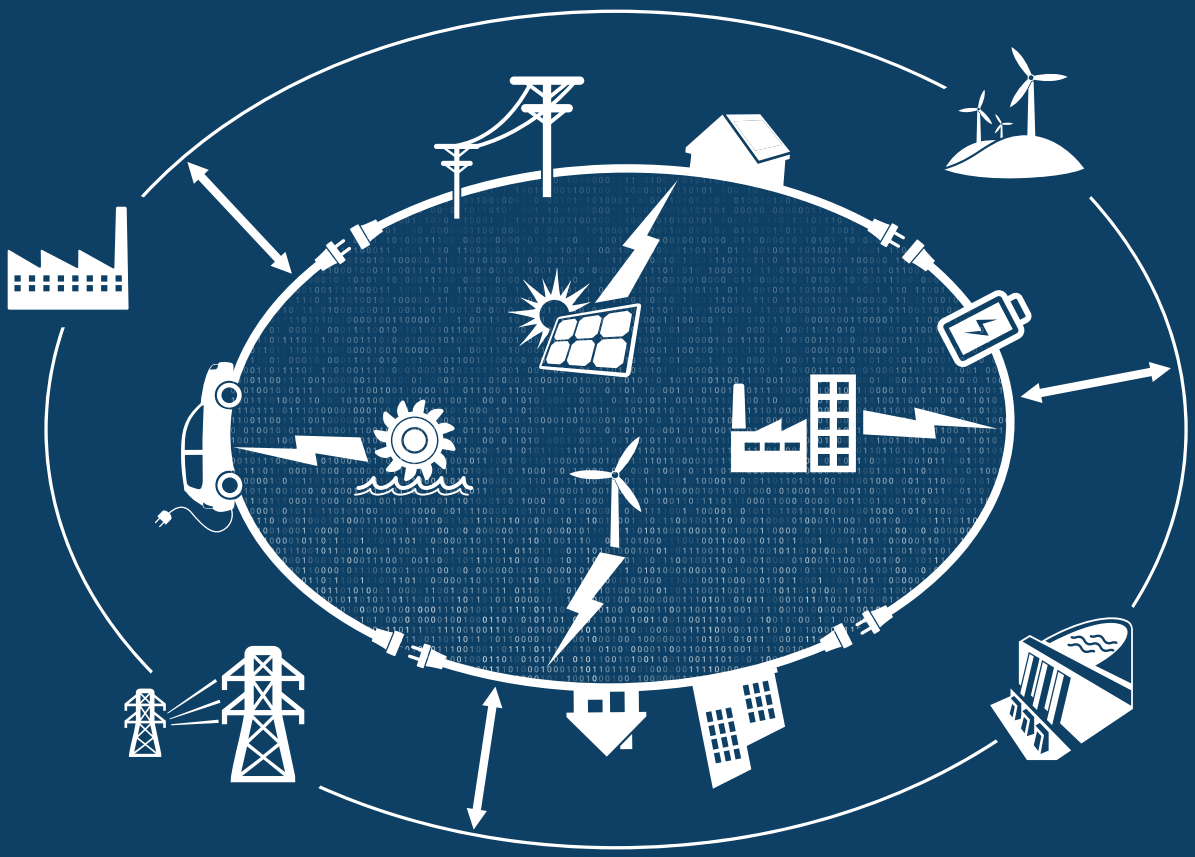
CINELDI
Centre for intelligent electricity distribution

Final report

CINELDI

CINELDI- a centre for environment-friendly energy research (FME), active from 2016 to 2024.

CINELDI worked towards digitalising and modernising the electricity distribution grid to achieve higher efficiency, flexibility, and resilience. CINELDI's results enable a cost-effective realisation of the future flexible and intelligent electricity distribution grid.



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Foreword

Gerd Kjølle

CINELDI is a centre for environment-friendly energy research, where we have spent the past eight years developing the electricity grid to ensure it is designed for the future, with a perspective towards 2030–2040.

CINELDI's focus has been primarily on regional and local distribution grids, as well as the interaction with the transmission grid. Our mission has been to facilitate renewable distributed power generation, the electrification of transport, and more efficient and flexible energy use.

Now that this eight-year project has come to an end, we have many results that we hope will be implemented and further developed. These results are available in CINELDI's knowledge base, which can be found on the Centre's website. More results and information are also available in the annual reports and in blog posts written by the scientists.

In this final report, we present some of our key findings at an overarching level and provide insight into how we have worked to share this knowledge widely. The report also highlights the Centre's impact – on society, industry partners, and research partners alike – as well as our efforts in education and international collaboration.

I am proud of what we have achieved together in this Centre. CINELDI has contributed in bringing the power grid to the forefront and establishing a collaborative forum for science and innovation in the field. Having such a large research centre as a platform for long-term collaboration has been crucial for all the partners. Building on what we have established in CINELDI, we successfully secured a new centre for environment-friendly energy research, SecurEL, which launched in 2025.

Gerd Kjølle
CINELDI's Centre director

Inge Gran

To reach our climate goals we need to push society toward greater electrification, and in this transition, the electricity grid is essential—it connects new renewable power sources with emerging consumption needs. In this pursuit, CINELDI has played a central role. The Centre has deepened our understanding of grid dynamics and innovative energy solutions—not least through pilot projects that have tested new technologies in real-world settings. It has served as a key meeting place for experts, industry leaders, technology users, and policymakers alike.

For SINTEF Energy Research, hosting CINELDI has been both an honour and a unique opportunity to drive forward world-leading research. Our closing conference in November 2024 highlighted CINELDI's important role as a platform where diverse ideas and expertise converged to shape the future of our energy infrastructure.

Looking ahead, the work we started with CINELDI is far from over. It will continue under the SecurEL banner—a development that has never been more relevant given today's global political challenges. We now understand that our energy system must be not only climate-friendly and cost-effective, but also resilient. The pioneering efforts of CINELDI have laid the groundwork for this crucial focus on security of electricity supply, which SecurEL will carry forward.

I want to extend my sincere gratitude to all the partners, research scientists, and stakeholders who made CINELDI such a success. Together, we have taken important steps toward securing a robust energy future, and I look forward to the continued progress in this next exciting chapter with SecurEL.

Inge Gran
CEO, SINTEF Energy Research

Summary

CINELDI's contribution to the overall goals of the FME scheme

CINELDI's objective has been to facilitate a cost-effective realisation of the future flexible and intelligent electricity grid. Through research, piloting, and innovation, the Centre has contributed to new knowledge and solutions that strengthen the grid's ability to handle the challenges associated with the integration of distributed renewable energy sources and the electrification of transport, while also facilitate better and more flexible utilisation of the grid.

Research results

The energy system is undergoing significant transformation due to the ambitious climate targets set by Norway and Europe for 2030 and 2050. Electrification of industries, transport, and other sectors are among the key measures to achieve these goals. The electricity grid plays a critical role in enabling electrification, by connecting consumption with power generation. As a result, CINELDI's research has become increasingly relevant over the past eight years.

CINELDI has published approximately 250 scientific articles. Digitalisation and flexible utilisation of the power grid have been two key overarching themes in research activities. Open access to publications, code, and data, while ensuring the anonymisation of sensitive data, has been a guiding principle. CINELDI has developed Norwegian reference grids that are valuable both for grid companies and further research and education. Additionally, the activities within the pilot projects have been crucial for CINELDI.

CINELDI's strategy and roadmap

CINELDI's strategy and roadmap for the transition to a flexible and intelligent power grid[1] is the result of an extensive strategic process within the Centre. The recommendations and advice derived from this process are based on the results and piloting conducted by CINELDI. The roadmap identifies the actions that various stakeholders should take to achieve this transition.

Awards

In 2020, Centre Director and Chief Scientist Gerd Kjølle received the honorary award from the Norwegian Academy of Technological Sciences (NTVA) for her work related to the security of supply in the electricity grid. Several of the Centre's research scientists have received awards for outstanding conference papers: Kasper Thorvaldsen (PMAPS Conference), Sigurd Bjarghov (EEM Conference), and Santiago Sanchez-Acevedo et al. (IEEE Industrial Electronics Society Conference).

Outcomes and Value Creation in Industry and Management

CINELDI's work has resulted in 50 innovations. Throughout the Centre period, the industry has strengthened its ability to adopt research results. Collaboration between grid companies facing similar challenges and innovation needs holds great potential.

The pilot projects were designed to benefit the entire industry. The grid companies in CINELDI are state-regulated monopolies, which results in fewer barriers to openly sharing results, especially regarding improved work processes. Code for integration into control centres, new algorithms, maintenance systems, and energy management frameworks are examples of results that have been shared and discussed among the partners.

The pilot project *Flexible power grid through dynamic operation* gave valuable results, including new technologies, better decision-making support, new collaborations, and innovations in work processes. The pilot project has contributed to a more efficient and data-driven grid operation. For technology providers, the Centre has helped open larger markets both nationally and internationally.

PhD and master's education

CINELDI has been home to 23 PhD candidates. Additionally, 7 postdoctoral researchers have been affiliated with the Centre. The PhD candidates and postdocs have made invaluable contributions to the knowledge development in the field.

A total of 150 students have completed their master's theses in CINELDI. Additionally, the Centre's research scientists have contributed to teaching at the master's level, as well as in the development of the new study program in Electrification and Digitalisation at NTNU.

International Collaboration

Since its inception in 2016, CINELDI has held a unique position internationally as one of the largest research centres in the field of smart grids, with key industry players represented in the consortium.

CINELDI researchers have actively participated in and led working groups and study committees which are central bodies for knowledge sharing, standardisation, and innovation in smart grids.

International collaboration has included case studies, PhD theses, idea and knowledge exchange in workshops and seminars, publications, participation in international projects, and institutional partnerships at the PhD, postdoctoral, and visiting researcher levels. CINELDI's senior research scientists have also served as opponents and participated in evaluation committees for many international PhD defences.

A research centre adds value

It has been crucial for all the partners to have a Centre for Environment-friendly Energy Research (FME) as a platform for long-term collaboration and an arena for generating ideas for new product development.

Eight years of collaboration have produced many meaningful discussions along the way. A research centre like this also provides valuable opportunities to address emerging challenges and explore new solutions as they arise. The world is constantly evolving, and since the Centre's inception in 2016, we have witnessed significant developments in technology. The energy situation in Europe is also changed.

The three-party collaboration between the technology providers, the grid companies and the scientists has been important for enabling a cost-effective realisation of the future flexible and intelligent electricity distribution grid. Collaboration on new solutions has contributed to the development of grid operations and increased standardisation in the industry, benefiting power grid companies, the Transmission system operator, and technology providers alike.

1. G. Kjølle, S. Sandell, O. Gjerde, M. Istad and M. Korpås, "CINELDI strategy and roadmap for transitioning to a flexible, intelligent power grid", CINELDI-report 04:2024

Sammendrag

CINELDIs bidrag til FME-ordningens overordnede mål

CINELDIs mål har vært å legge til rette for en kostnadseffektiv realisering av det fremtidige fleksible og intelligente strømnettet. Gjennom forskning, pilotering og innovasjon har senteret bidratt til ny kunnskap og nye løsninger som gjør strømnettet bedre rustet til å håndtere utfordringene knyttet til integrasjon av distribuerte fornybare energikilder og elektrifisering av transport, og lagt til rette for mer effektiv og fleksibel energibruk.

Forskningsresultater

Energisystemet er i stor endring som følge av de ambisiøse klimamålene som Norge og Europa har satt for 2030 og 2050. Elektrifisering av industri, transport og andre sektorer er blant de viktigste tiltakene for å nå disse målene. Strømnettet er en kritisk tilrettelegger for elektrifiseringen fordi det knytter sammen forbruk og kraftproduksjon. CINELDI og forskningen har som følge av dette blitt mer relevant gjennom disse åtte årene.

CINELDI har i publisert ca. 250 vitenskapelige artikler. Digitalisering og fleksibel utnyttelse av strømnettet har vært to viktige overordnede tema for forskningsaktiviteten. Åpen publisering og deling av kode og data har vært en viktig rettesnor – samtidig som anonymisering av sensitive data er essensielt. CINELDI har utviklet norske referansenett som er nyttige, både for nettselskaper og i videre forskning og undervisning. I tillegg har aktiviteten i pilotprosjektene vært viktig for CINELDI.

CINEDIs strategi og veikart

CINELDIs Strategi og veikart for overgangen til et fleksibelt og intelligent strømnett[2] er resultatet av en omfattende strategiprosess i senteret. Rådene og anbefalingene som kom ut av dette er basert på forskningen og piloteringen som er gjort i CINELDI. Et veikart viser hvilke tiltak som bør gjøres av ulike aktører for å få til denne overgangen.

Utmerkelser

Senterdirektør og sjefforsker Gerd Kjølle mottok i 2020 Norges Tekniske Vitenskapsakademi (NTVA) sin ærespris for sitt arbeid knyttet til forsyningssikkerhet i strømnettet. Flere av senterets forskere har mottatt priser for gode konferanseartikler: Kasper Thorvaldsen (PMAPS-konferansen), Sigurd Bjarghov (EEM-konferansen) og Santiago Sanchez-Acevedo et.al (IEEE Industrial Electronics Society-konferansen).

Industrielle og forvaltningsmessige resultater og nytteverdi

CINELDIs arbeid har resultert i 50 innovasjoner. Gjennom senterperioden har bransjen økt sin evne til å ta i bruk forskningsresultater. Samarbeid mellom nettselskaper med like utfordringer og innovasjonsbehov har stort potensial.

Pilotprosjektene kommer hele bransjen til gode. Nettselskapene er statlig regulerte monopoler, noe som gir færre barrierer for å dele resultater åpent, særlig innen forbedrede arbeidsprosesser. Kode for integrasjon i kontrollsentre, nye algoritmer, vedlikeholdssystemer og rammeverk for energistyring er eksempler på resultater som er delt og diskutert blant partnerne.

Pilotprosjektet *Fleksibelt strømnett gjennom dynamisk drift* har gitt verdifulle resultater i form av ny teknologi, bedre beslutningsgrunnlag, nye samarbeid og innovasjoner i arbeidsprosesser. Pilotprosjektet har bidratt til mer effektiv og datadrevet drift av nettet.

For teknologiutviklere har CINELDI vært en døråpner til større markeder, både nasjonalt og internasjonalt.

Forskerutdanning og masterutdanning

CINELDI har hatt 23 PhD-kandidater. I tillegg har 7 postdoktorer vært tilknyttet senteret. PhD-kandidatene og postdoktorene har gitt et uvurderlig bidrag til kunnskapsutviklingen på feltet.

150 studenter har skrevet masteroppgave i tilknytning til CINELDI. I tillegg har senterets forskere bidratt i undervisning på mastergradsnivå, samt i utviklingen av det nye studieprogrammet Elektrifisering og digitalisering

Internasjonalt samarbeid

CINELDI har, siden oppstarten i 2016, hatt en unik posisjon internasjonalt som et av de største forskningssentrene innen smarte nett, med sentrale aktører i bransjen representert i konsortiet.

CINELDI-forskere har deltatt i og ledet arbeidsgrupper og studiekomiteer i organisasjoner som er sentrale for kunnskapsdeling, standardisering og innovasjon innen smarte nett.

Internasjonalt samarbeid har blant annet vært knyttet til case-studier, doktorgradsavhandlinger, idé- og kompetanseutveksling i workshops og seminarer, publikasjoner, deltakelse i internasjonale prosjekter og institusjonelle partnerskap på PhD-, postdoktor- og gjesteforskernivå. CINELDIs seniorforskere har også vært opponenter og deltatt i bedømmelseskomiteer for flere internasjonale PhD-disputaser.

Et forskningssenter gir merverdi

For alle partnere i senteret har det vært avgjørende å ha et forskningssenter for miljøvennlig energi (FME) som en plattform for langsiktig samarbeid og en arena for å ta tak i nye ideer og utvikle løsninger.

Åtte år med samarbeid har lagt til rette for gode og meningsfulle diskusjoner underveis. Et slikt senter gir også verdifulle muligheter til både å ta tak i nye utfordringer og utforske og teste nye løsninger som dukker opp. Verden er i stadig endring, og siden oppstarten i 2016 har vi sett betydelige fremskritt innen teknologiutvikling, i tillegg til at situasjonen for energiforsyningen i Europa har endret seg.

Tre-partssamarbeidet mellom teknologileverandørene, nettselskapene og forskerne har vært viktig for å muliggjøre en kostnadseffektiv realisering av det fremtidige fleksible og intelligente strømnettet. Samarbeid om nye løsninger har bidratt til utvikling i drift av nettet og økt standardisering i bransjen, til fordel for både nettselskaper, systemoperatør Statnett og teknologileverandører.

2. G. Kjølle, S. Sandell, O. Gjerde, M. Istad og M. Korpås, "Strategi og veikart for overgangen til et fleksibelt og intelligent strømnett", CINELDI-rapport 03:2024.

Vision and goals

VISION

Developing the electricity grid of the future.

MISSION

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

GOAL

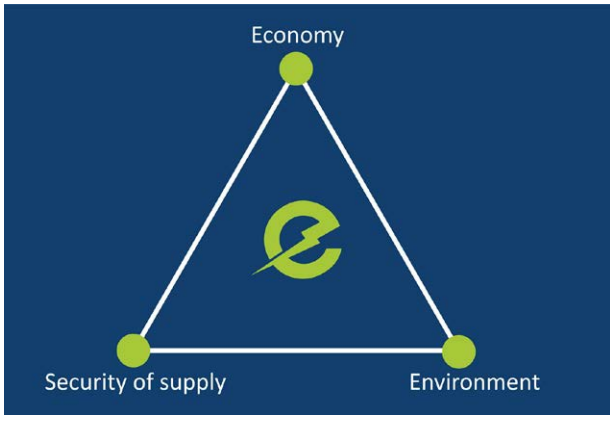
To enable and facilitate a cost-efficient realisation of the future flexible and robust electricity distribution grid.

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

The vision and main objective remained unchanged during the centre period. CINELDI's goal got even more relevant during the eight years, as the importance of electrification increased.

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.



A sustainable power grid for the future considers the balance in the energy trilemma between security of supply, cost-effectiveness and climate/environmental considerations.

Photo: Shutterstock

Security of electricity supply

CINELDI has ascertained that, on the one hand, the ongoing electrification may compromise security of supply, while on the other hand, digitalisation and the utilisation of flexibility provides potential for new ways of handling security of supply in the future. Security of electricity supply comprises energy security, power security (capacity), reliability of supply and voltage quality. This also includes operational reliability, cybersecurity and personal safety. Security of supply has not been one of the principal themes of CINELDI, apart from activities connected with cybersecurity, but new issues and research needs have been identified connected with security of supply in the power grid of the future.

Environment-friendly grid

CINELDI has contributed to national energy and climate goals on the road to a low-emission society. This has principally involved facilitating increased distributed energy generation from renewable sources (solar, wind, hydroelectric), electrification of transport and more flexible power and energy consumption, by making better use of existing power grids and without building more new grids than necessary.

Economy: Cost-effective grid

One of CINELDI's goals has been to contribute to a cost-effective realisation of the electricity grid of the future, by finding **socio-economically** optimal solutions for the grid, in line with the Norwegian Energy Act [Energiloven]. This means that the goal is to find solutions that minimise total system costs (the sum of operating and investment costs), while ensuring a flexible, intelligent and robust power grid. CINELDI's research has focused on opportunities for improving utilisation of the power grid, which will contribute to reducing total costs.


Photo: Shutterstock

Effects of the Centre for the overarching goal of the FME-programme

Increased innovation and value creation

Through CINELDI, power grid companies have become better equipped to implement new solutions within their organisations. CINELDI has contributed to various types of innovations, including methodologies, guidelines, models, and data sets. These innovations stem from both research and pilot projects. In different ways, they support the digitalisation and modernisation of the electricity distribution grid, ensuring higher efficiency, flexibility, and resilience. A stronger data foundation and insights, along with new technological solutions, are transforming the way power grid companies plan and operate the power grid. New methods and models contribute to this transformation as well. This transformation will support increased electrification and enhanced value creation in society.

A smarter power grid for a sustainable future

Better operation of the power grid, with higher utilisation of capacity, contributes to increased electrification of transport, industry, and other sectors of society. This leads to reduced greenhouse gas emissions and paves the way for a zero-emission society by 2050. A well-managed and efficiently utilised power grid enables the transmission of more renewable energy from producers to consumers. Increased solar and wind power generation places new and more complex demands on the grid. Improved insights and digital solutions developed within the Centre equip power grid companies to address many of these emerging challenges.

CINELDI's strategy and roadmap for transitioning to a flexible and intelligent electricity distribution grid will enable higher utilisation of the grid, better integration of renewable and flexible energy resources, and increased electrification of industry, transport, and other sectors. This, in turn, will help reduce CO_2 emissions and enhance value creation.

The effect study is carried out on behalf of the Ministry of Energy.
The cases mentioned here are from CINELDI and the projects GARPUR, FASaD and FlexPlan.

The effect study

Risk-based planning and operation of the power grid

The power grid is challenged by the increasing integration of variable renewable generation and growing power exchange. By using risk-based methods, we can achieve faster electrification and significant investment savings.

Concrete models and tools enable the calculation and comparison of the socio-economic cost of different operational strategies. Results show:

1. Increased utilisation of the power grid allows for the rapid connection of more renewable energy.
2. The methods enables grid expansion to be postponed or scaled down.

The models quantify cost elements and provide valuable insights for system operators. Several grid operators have adopted parts or the entirety of the method. The estimated net present value, assuming a 5% reduction in expected transmission grid investments in Norway from 2023 to 2032, is up to NOK 7.5 billion.

Fault and interruption management

Smarter fault and interruption management using fault current indicators and self-healing grids results in shorter power supply interruptions and reduced socio-economic costs.

Power supply interruptions can lead to significant socio-economic costs. Fault current indicators and self-healing grids help locate and isolate faults, enabling power restoration as quickly as possible. This functionality has the potential to reduce both the frequency and duration of interruptions.

Research results have led to changes in work processes related to fault and interruption management, resulting in lower operational costs. They have provided a better basis for decision-making, and increased expertise in both fault and interruption solutions and reliability analysis involving smart grid technology.

Calculations show that interruption costs can be reduced by 30–50% using short-circuit and earth fault indicators combined with remotely controlled sectionalising switches, compared to conventional fault and interruption management. This corresponds to a potential reduction of approximately NOK 125 million in annual KILE costs (Costs of energy not supplied) in Norway, with a net present value of around NOK 1 billion over ten years.


Photo: Falkebilkk/Linja

Dynamic operation of overhead lines

Research on overhead lines equipped with smart sensors has shown that the lines have more capacity than current limits suggest for more than half the time throughout a year.

Today, most power grids operate based on static safety limits and experience-based models and forecasts, with relatively few sources of real-time data. The transmission capacity of the Norwegian power grid, based on these limits, is constrained. With increasing electrification, there is a growing need to expand capacity to accommodate new consumption. Building new grid infrastructure takes time, while the number of connection applications has surged in recent years. Optimising the use of the existing grid is essential to meet the rising demand for electrification.

Through research, an improved and commercialised product has been developed for the global market. Power grid companies have gained valuable insights and real-time data from their grids, allowing for more dynamic grid operation. This means power flows can be adjusted and optimised based on actual conditions, enabling the connection of more customers without expanding the grid. A framework has also been developed to integrate data into SCADA systems (supervisory control and data acquisition), which is crucial for daily operations.

As an example, a grid company was able to accommodate increased capacity from a wind power plant by instrumenting two critical lines. This allowed the company to avoid investments of approximately NOK 200 million, and the wind power producer did not have to wait for additional grid capacity.

Power grid planning with flexibility in mind

Using flexibility as a supplement to grid expansion can enable faster connections of new electricity consumption and generation while improving grid utilisation.

Flexibility refers to the ability and willingness to modify production and/or consumption patterns to provide a service to the power system or to maintain stable grid operation. Flexible resources include production units, consumption assets, and energy storage systems, where injected or consumed power can be adjusted based on agreements with the grid company and/or a third party (e.g., an aggregator) to support system operations.

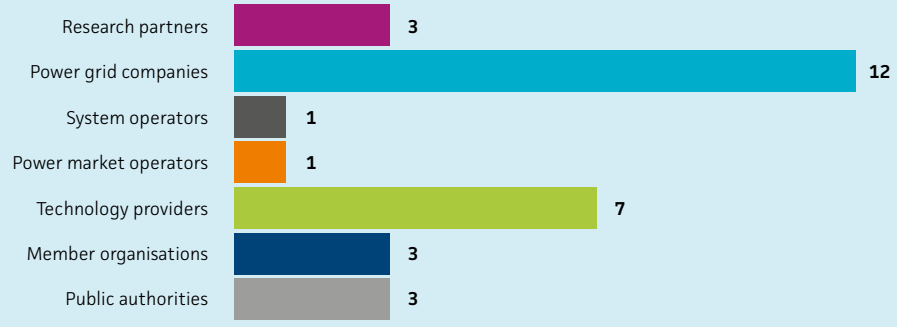
The Flexplan tool is a large optimisation model that simulates power flow and socio-economic costs across the entire Nordic power system. The model suggests the most economically optimal combination of measures. This methodology can be used to estimate investment needs and assess the potential role of flexibility in grid development.

One key conclusion from this work is that flexibility should no longer be seen merely as an alternative to grid expansion—it is more accurately regarded as a supplement to it.

Basic facts about the Centre

Partners

The CINELDI consortium started with 28 partners at launch, and grew to 30 partners by 2024.



Merging and name changes of DSOs
The number of power grid companies in Norway changed significantly during CINELDI's period of activity; decreasing from approximately 125 in 2016 to around 90 in 2024. Some of CINELDI's grid company partners underwent mergers and name changes. After the mergers, CINELDI had 12 partnering power grid companies accounting for over 70 % of Norway's power supply.

Partners joining and leaving
Six new user partners were recruited between 2017 and 2021. Two technology providers and one market operator left the consortium due to changes in their business strategies.

These partners were part of the consortium for a part of the Centre period:

- Eltek (2016–2019)
- Powel (2016–2020)
- Nordpool (2018–2021)
- Haugaland Kraft – now Fagne (2018–2024)
- Disruptive Technologies (2019–2024)
- Prediktor (2020–2024)
- NODES (2020–2024)
- Heimdall Power (2021–2024).

Partners at the end of the Centre period

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 Organisations

Reneawbles Norway

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

Organisation

The Centre Management team handled the overarching coordination and communications with the partners, the Research Council, the Scientific Committee and the Executive Board. The team also had an extended management group, which included the Centre Management, the WP-leads and coordinators from the research partners not represented in WP management.

Some changes were made to the Work Packages (WPs) during the Centre period. In addition to the four shown in the figure, CINELDI initially included two other WPs: Microgrids/Local Energy Communities (LEC) and Flexible resources in the power system. Their planned activities were later integrated into the remaining WPs.

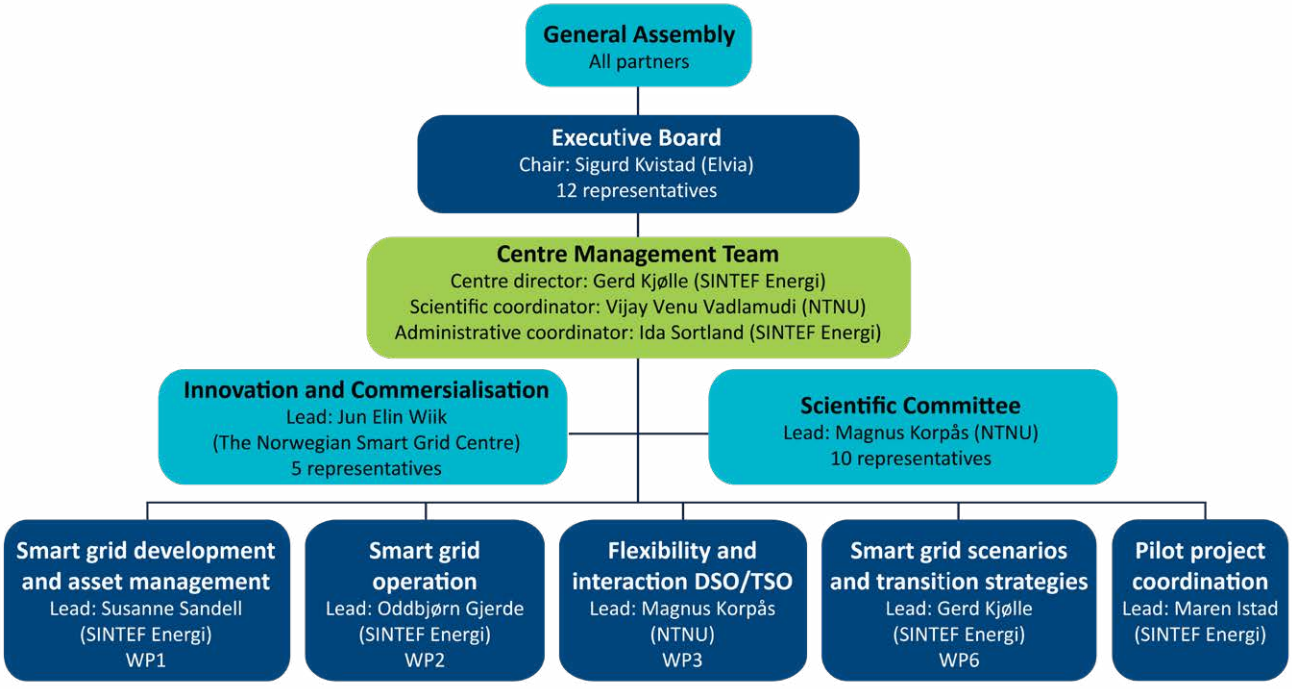


Figure: The organisation structure at the end of the Centre period.

Centre management

Gerd Kjølle
Centre Director and
WP Lead 2016-2024
SINTEF Energy Research

Vijay Vadlamudi
Scientific coordinator
2023-2024
NTNU

Ida Sortland
Administrative
coordinator 2021-2024
SINTEF Energy Research

Susanne Sandell
WP Lead 2023-2024
SINTEF Energy Research

Oddbjørn Gjerde
WP Lead 2016-2024
SINTEF Energy Research

Magnus Korpås
WP Lead 2016-2024
and Leader of Scientific
Committee 2019-2024
NTNU

Maren Istad
Pilot project
coordinator 2019-2024
SINTEF Energy Research

Senior research scientists

Merkebu Z Degefa
WP Lead 2022-2023
SINTEF Energy Research

Olav Bjarte Fosso
Scientific coordinator
2021-2023 and
WP Lead 2018-2020
NTNU

Poul Heegaard
WP Lead 2016-2018
NTNU

Morten Hovd
Leader of Scientific
Committee 2016-2018
NTNU

Ole-Morten Midtgård
WP Lead 2016-2017
NTNU

Kjell Sand
Scientific coordinator
2016-2020
NTNU

Hanne Sæle
WP Lead 2016-2022
SINTEF Energy Research

Henning Taxt
WP Lead 2019-2022
SINTEF Energy Research

Gencer Erdogan
SINTEF Digital

Pedro Crespo del Granado
NTNU

Sture Holmstrøm
SINTEF Digital

Martin Gilje Jaatun
SINTEF Digital

Geir Mathisen
SINTEF Digital

Santiago Sanchez-Acevedo
SINTEF Energy Research

Tomas Moe Skjølsvold
NTNU

Iver Bakken Sperstad
SINTEF Energy Research

Raymundo E. Torres-Olguin
SINTEF Energy Research

Inger Anne Tøndel
SINTEF Digital

Tesfaye Amare Zerihun
SINTEF Energy Research

Executive Board

The Executive Board met four times a year. At the end of CINELDI's period, the Board consisted of the following members:

Sigurd Kvistad
Chair of the Executive Board
Elvia

- Sigurd Kvistad, Elvia
- Svein Kristian Reiersen, Lnett
- Tom-Rune Bjørtuft, ABB Electrification Norway
- Stig Simonsen, Lede
- Ingvill Stenseth, BKK
- Per-Oddvar Osland, Glitre Nett
- Bjørn Bakken, Statnett
- Kristin Lind, Renewables Norway
- Hermund Slaatsveen, Aidon
- Espen Kåsin, Embriq
- Anngjerd Pleym, NTNU
- Knut Samdal, SINTEF Energy Research
- Khanh Tuan Le, Research Council of Norway (Observer)

Innovation Committee (IC)

Grete Coldevin
IC lead 2016-2020
The Norwegian Smart Grid Centre

Jun Elin Wiik
IC lead 2022-2024
The Norwegian Smart Grid Centre

Scientific Committee (SC)

The Scientific Committee (SC) was a platform for dialogue between CINELDI and key international partners. The SC discussed matters regarding the Centre's direction, lab activities, scientific ambition, and international relevance. The WP leaders and Centre Management participated in all SC meetings to ensure close contact between research scientists and international advisors. Several SC members are involved in international research related thematically to CINELDI.

In June 2023 the Scientific Committee had a workshop in Trondheim. Front row, left to right: Mattia Marinelli, Madeleine Gibescu, Gerd Kjølle, Anne Remke. Back row, left to right: 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

Cooperation within the Centre

Partners and their impact

Building the smart, flexible, robust grid of tomorrow in a cost-effective way requires a huge effort from all parts of the industry: the authorities setting the industry's regulatory framework, the Transmission system operator and grid companies operating the grid, technology providers to the sector, and stake-holder organisations such as Renewables Norway and the Norwegian Smart Grid Centre. CINELDI has had active partners, putting in hard work and dedication towards the joint goals.

Cooperation between partners

The Centre's goal has been to establish three-party collaboration between technology providers, grid companies and research scientists to facilitate best practice sharing and accelerate the implementation of new technology. One of the keys to CINELDI's success is the cooperation and knowledge sharing between partners. Another is the co-creation between

technology providers, power grid companies, system operators, member organisations and research partners. This diversity of perspectives enabled them to collaborate effectively and develop new solutions.

Pilot projects: A platform for collaboration
Pilot projects provided a valuable framework for cooperation between R&D partners and user partners. Thanks to our multidisciplinary research approach, R&D partners collaborated closely across all work packages (WPs). Partners were also tightly integrated into CINELDI's work process. For example, representatives from across the Centre participated in idea generation, research planning, and reviews. Partners were involved in discussing new ideas at workshops, as well as through dedicated expert groups within each WP. The WPs actively used the expert groups every year when developing their work plans.

Meeting points
CINELDI had a clear plan for user partner involvement, and focused on creating valuable arenas for collaboration. Before the pandemic, Centre managers visited partners more frequently. During the pandemic, the Centre successfully established digital meeting points, with webinars emerging as particularly successful. These online events showcased research findings, pilot projects results, and updates from the Centre's PhD candidates.

In the period following the pandemic, CINELDI managed to gather an increasing number of participants from partner companies for joint physical meetings, webinars, workshops, and events. The Centre had two regular consortium-wide events annually: the CINELDI Workshops in the spring, and the CINELDI Days in the autumn. Some of these meeting points have also been open for others outside the consortium.

These forums allowed for sharing research results and for knowledge exchange among partners. Such collaborative efforts support the consortium's common objective: to realise the future power grid. Centre Management was pleased to observe a high level of engagement, and to see new 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 meeting with scientists has been a positive aspect of their participation in the Centre.

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

- Guest visits from the industry to the National Smart Grid Laboratory, and workshops associated with the lab at NTNU and SINTEF Energy Research.
- Partner meetings including visits where the centre management has visited a user partner and met with both management and R&D department.
- Workshops with research institutions, utilities, and technology companies in connection with pilot projects.
- PhD candidates visiting a grid company, and CINELDI PhDs doing research stays abroad with Scientific committee representatives.
- PhD and postdoctoral fellows from other projects going on research stays with NTNU and SINTEF Energy Research.

Financing through the life of the Centre

Contributor	Cash	In-kind	Total
Host		27 219	27 219*
Research partners		23 937	23 937*
Companies	64 450	113 804	178 254
Public partners	2 600	608	3 208
RCN	160 000		160 000
Sum	227 050	165 568	392 618

**The inkind from the research partners including the host consists of work done in RCN Competence projects and EU-projects affiliated to the centre. The RCN Competence projects are e.g., FuChar, FINE, Multigrid and ROME.*

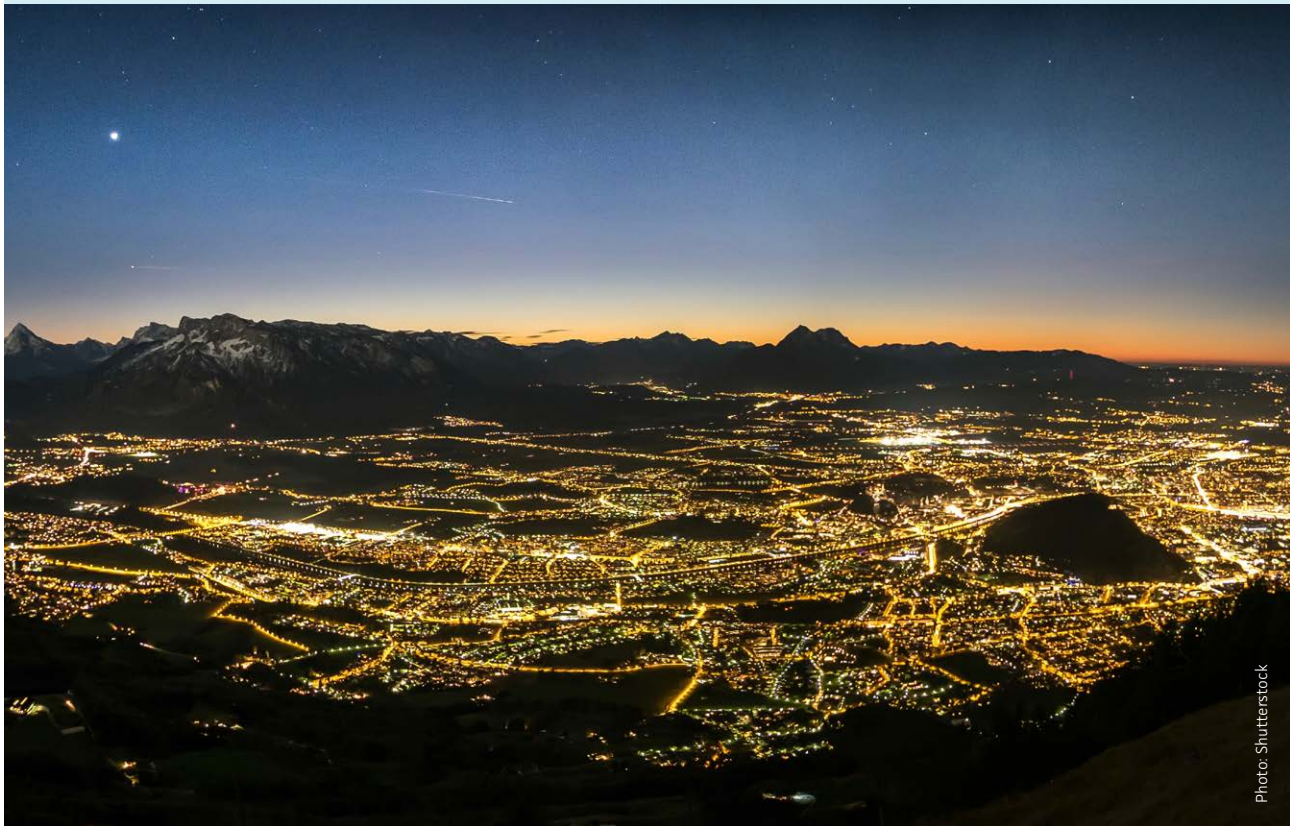


Photo: Shutterstock

Results - Key figures

	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total
Scientific publications (peer reviewed)	1	2	18	33	29	58	28	33	49	251
Dissemination measures for users	19	23	56	79	13	52	74	25	39	380
Dissemination measures for the general public	23	17	22	27	36	13	30	22	26	216
Research Innovations*			4	2	14		5		12	37
Number of new/ improved methods/ models/proto-types finalised			3	1	21	1	12	1	24	63
Number of new/ improved products/ processes/services finalised			1			1	1		8	11
PhD-degrees completed						2	3	1	1	7
Master degrees		3	19	23	33	21	20	16	15	150

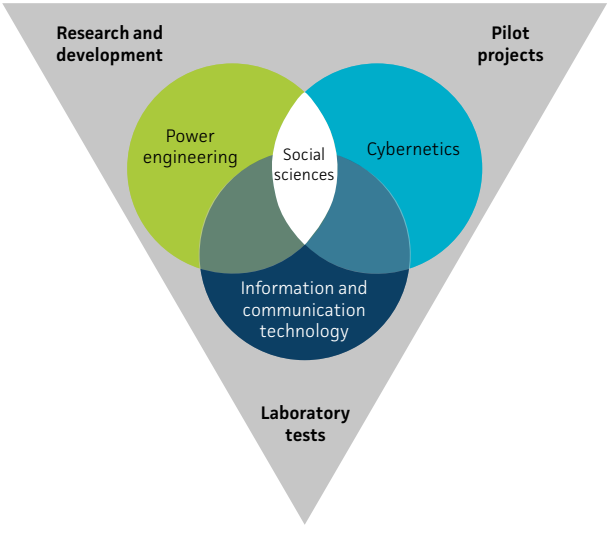
*There are 37 reported potential innovations from research activities, of these are 31 described at CINELDIs website (**www.sintef.no/projectweb/cineldi/innovation**) In addition, there are 19 innovations from pilot projects.

Research strategy

Multidisciplinary research platform

CINELDI's research was based on a multidisciplinary platform consisting of three pillars: research and development, laboratory tests and pilot projects. The research activities were performed in close collaboration across four main disciplines: electric power engineering, cybernetics, information and communication technology, and social sciences. The latter played a key role in analysing social economics and consumer behaviour related to flexibility. The Centre's research activities were organised in six research areas.

The research areas reflected the main aspects of power system operation and management. This ensured that each area addressed research questions that were highly relevant to both industry and society. Furthermore, this structure enabled academic partners to work in close collaboration across disciplines. It facilitated interaction and communication between partners from research and industry alike.



Through basic and applied research, CINELDI's scientists provided in-depth knowledge, methods, and tools that were tested in laboratories, simulated environments, and small-scale field pilots (also known as *living labs*).

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

Shifting focus to grid utilisation and security of electricity supply

Midway through the Centre's period, CINELDI shifted towards a more concentrated and focused effort to better **utilise the power grid**. Centre management recognised that electrification had become an even stronger driver of change, something also emphasised in UN reports from 2021 and 2022 on climate change accelerating and the increasing urgency to take action The pressure for electrification in industry and the transportation sector increased significantly. Both Statnett and the power grid companies experienced a surge in grid connection requests.

Centre management realised that electrification and better utilisation of the power grid would impact **security of electricity supply**, prompting a shift in research focus. Meanwhile, public concern over energy security grew. This was due to several factors, including Russia's invasion of Ukraine in 2022, which led to an energy crisis and soaring electricity prices, as well as

The pressure for electrification in the transportation sector has increased during the Centre's period.

emerging cyber threats, and climate change causing more extreme weather events.

These developments have made CINELDI and its research even more relevant as the years progressed – highlighting the importance of optimising the use of the existing power grid and avoiding unnecessary construction of new grid infrastructure.

The mid-term evaluation was a useful milestone for such a large project with many partners. Centre management and the Executive Board used the feedback from the Research Council and the external committee to make necessary adjustments between the first and second halves of the project. Following the review, the Centre took the opportunity to conduct a thorough strategic process within the consortium. Separate meetings were held involving all partners and the Scientific Committee. The results of the midterm evaluation and internal review were used to adjust the strategy and work plans for the final years of the project.

Research achievements and highlights of scientific results

CINELDI had six research areas.
Results from each of these topics can be found in **CINELDI's Knowledge base** on the website.

Smart grid development and asset management
Decision-support methodologies and tools needed for the optimal planning and asset management in a smart electricity distribution grid.

Smart grid operation
Advanced monitoring and operation of the future distribution grid requires the secure utilization of new ICT technologies and the development of new operational concepts.

Interaction DSO/TSO
New solutions for flexible resources in different products and ancillary services, to increase observability between the distribution and transmission systems, and to develop business models for customer flexibility.

Microgrids/local energy systems
Concepts, technologies, and models for microgrids and their interaction with the distribution system, together with real-time monitoring between all assets, grid customers and flexible resources.

Research areas

Flexible resources in the power system
Methods and strategies for the cost-effective integration of flexible resources in smart distribution grids for improved efficiency of the system operation and a realistic alternative to grid investments.

Smart grid scenarios and transition strategy
Visions and scenarios for a smart grid, and guidelines and recommendations for implementing results in the electricity industry.

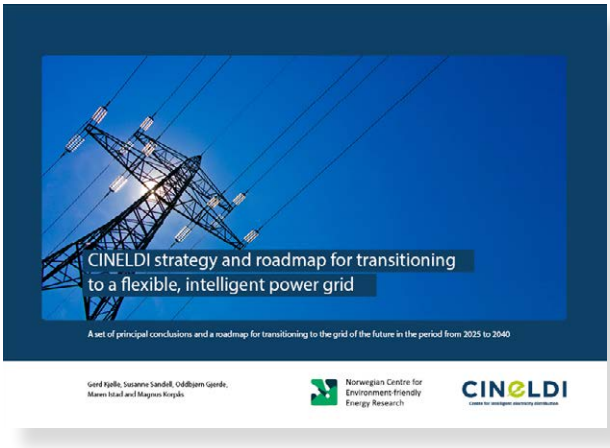
CINELDI strategy and roadmap for transitioning to a flexible, intelligent power grid

This report summarises the results of a comprehensive strategy process in which the entire FME CINELDI consortium was involved. The strategy process was research-based, which means that it is founded on the research and pilot projects carried out by CINELDI. The work has led to several recommendations, organised in the form of three principal conclusions, which CINELDI believes are crucial to achieving the necessary transition of the electricity grid in the period 2025 to 2040:

1. Widespread digitalisation and automation are necessary to gain insight into and enable control of the power grid: To enable the optimal utilisation of the grid, we must have insight into how it operates and be able to control it using active measures. This necessitates digitalisation and automation.

2. Flexibility in the consumption, generation and storage of electricity is needed to achieve better utilisation of the power grid. Flexibility must be implemented to be able to connect as much consumption and new generation as possible, and to achieve better utilisation of the grid.

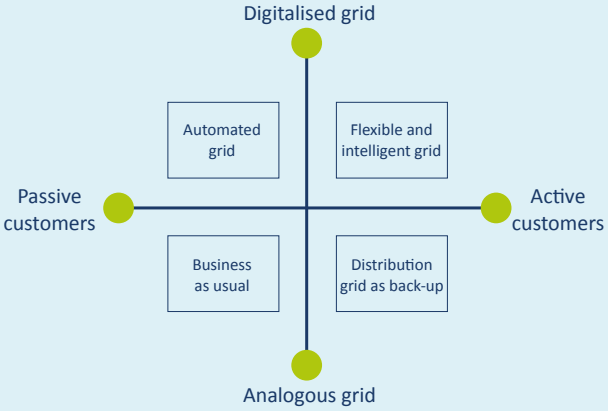
3. Security of electricity supply may be compromised by extreme weather, cyber threats, increased operating loads and increased complexity of the power system, and must be handled differently in the future: Digitalisation and flexibility provide opportunities for discovering new ways of managing security of supply.



Scenarios for the power grid of the future

CINELDI has identified driving forces through a foresight process. Based on them, four principal scenarios have been established along two axes.

An *analogous* distribution grid largely resembles the existing grid and grid operation. In an analogous grid, new technology is made use of to a limited extent and work processes (connected with operation, planning and maintenance) are automated to a limited extent. In a *digitalised* grid, widespread use is made of technology to enable improved observability and automation, both in the physical distribution grid and in the work-processes connected with planning, operation and maintenance of the grid.



Passive customers are grid customers whose consumption and/or production/storage do not contribute to the flexibility of the power system. *Active customers* are grid customers whose consumption and/or production/storage contribute to the flexibility of the power system.

Photo: Shutterstock

Digitalisation and Automation

Digitalisation has been essential for achieving CINELDI's vision of a flexible and intelligent grid.

Digitalisation and automation of the power grid are broadly about using technology to improve, simplify, and renew work processes in grid planning and operation. At CINELDI, we have worked on large parts of the digitalisation chain: from sensors, through modelling and analyses, to carrying out actions in the power grid. We have also addressed issues related to the disadvantages of digitalisation. Digitalisation exposes the grid to new vulnerabilities, both by increasing system complexity and by opening systems to the outside world. Mapping risk and vulnerabilities, as well as cybersecurity, have therefore been central.

Why have we worked on digitalisation and automation?
Grid capacity is a bottleneck for further electrification in Norway. There are long queues for grid connection, affecting both power generation and consumption, and the queues are growing rapidly. To electrify society, it is necessary to increase grid capacity quickly.

New grids must be built, but this takes time. Therefore, we need to make better use of the existing grid. At the same time, we want to optimise the building of new grids, to ensure cost-effective solutions and to reduce land use and environmental impact.

We achieve this without compromising security of power supply, through innovative measures and improved work processes for grid planning and active grid operation, made possible by digitalisation and automation solutions.

FACTS
Digitalisation involves:
- Developing and implementing new measurement methods and sensors to access the information necessary for planning and operating the power grid.
- New communication solutions, both for collecting critical real-time information and for secure and reliable execution of necessary actions.
- Combining information from sensors and models into knowledge that can be used for decision support and control.

Automation means using technology to make decisions and carry out actions with little or no human involvement. The motivation for automation is that the process is either too fast or too complex to rely on human intervention, or that human resources can be freed up by automating less critical processes.

FACTS
Security of electricity supply is the power system's ability to continuously deliver electricity of a given quality to the end-user (NVE-RME, 2022).

The many facets of digitalisation
Nearly all our work at CINELDI involves digitalisation in some way, covering a broad scope: from sensor technology and data collection to advanced grid and component modelling. These elements come together to support decision-making for operators and enable control and automation in the power grid.

A) Data collection
Sensor technology and data collection involve gathering data from the power grid and surrounding systems that affect it. This can include, for example, electrical parameters, component and environmental temperatures, and information about the condition of various components and systems. Data collection requires some form of communication system to collect the data in real-time. At CINELDI, we have studied the use of 5G technology for critical communication.

B) Processing
In terms of data processing and usage, we have worked with load models, grid models for planning and operation, component condition models and various models related to maintenance and reinvestments.

C) Decision-making
Based on analysis results, the necessary decisions are made. This can happen manually—with the results serving as decision support for an operator—or through various levels of automation. Examples include voltage regulation, the use of dynamic load limits, remote control and reconfiguration of the grid, activation of flexible resources, self-healing grids, and ultimately, fully automated grid operation as a vision for the future.

For practical use, the information from all sources must be integrated into the different support and operational systems of the grid companies and presented in appropriate ways so that operators and grid developers can use it as decision support or as input for automatic solutions.

Three examples of results

How to use smart meters for monitoring and managing the distribution grid
CINELDI has created a physical lab setup in the National Smart Grid Laboratory to explore how information from smart meters can be utilised in advanced control centres. As more distributed energy sources like solar are added, it becomes harder for operators to monitor and manage the distribution grid. This creates a need for new methods to monitor and validate the state of the distribution grid.

CINELDI's lab setup includes physical smart meters in a modelled grid, which can be used to validate various functions and techniques, such as topology identification, state estimation, and advanced control based on optimal power flow.

Three examples of results

How to exchange information between DSOs and the TSO for coordinated voltage regulation and congestion management

CINELDI has studied data exchange between distribution system operators (DSOs) and the system operator Statnett (TSO) and developed a system to test this in the National Smart Grid Laboratory. Results show that even simplified models can have great value.

Distributed energy sources bring new operational challenges, such as voltage regulation and congestion management. They also make the interaction between the distribution and transmission grids more complex, requiring close coordination between DSOs and the TSO.

CINELDI has studied the need for data exchange between DSOs and the TSO for real-time operational coordination of reactive power for voltage regulation. We developed a test system where the physical grid is simulated in a real-time simulator, and critical information such as setpoints is exchanged according to the IEC 60870-5 standard. This is a standard for information exchange between two operating systems.

Our results show that losses can be reduced if the TSO gains access to detailed models of the distribution grids. Detailed models may be difficult to produce, but simplified models also provide significant benefits. Information exchange between DSOs and the TSO based on the CGMES specification (Common Grid Model Exchange Specification) has proven sufficient for operational coordination.

Three examples of results

How to assess vulnerabilities and risks for grid solutions at the conceptual stage

When planning new grids, various solutions and approaches are often compared, e.g.: Is it enough to reinforce the existing grid, or is new grid construction required? Should a solution involving self-healing grids be chosen to increase capacity while ensuring adequate security of power supply?

For each alternative solution, the grid company must assess which new risks and vulnerabilities are introduced. At CINELDI, we developed a tool to support cybersecurity assessments already at the grid planning phase, at a conceptual stage, often years before specific solutions are chosen and equipment is specified. CINELDI suggests a six-step method, and we have created an open-access tool based on approaches used in other industries.

Experience from other industries shows that this method is applicable without requiring expertise in cybersecurity, and we have adapted it to help grid planners address the challenges they face. The method was tested on a real case, where self-healing grids were evaluated. Preliminary results show that the method is highly beneficial for grid planners.

Photo: Shutterstock

Flexibility and flexible resources

At CINELDI, we have worked extensively on how power generation and electricity consumption can be adjusted to utilise the grid's capacity more effectively than today.

FACTS
Flexibility is the ability and willingness to modify production and/or consumption patterns, either on an individual or aggregated level, often in response to an external signal, to provide a service to the power system or maintain stable grid operation.

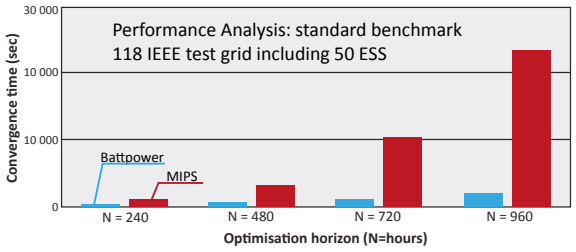
In Norway we already have a flexible power system due to hydropower. However, energy consumption is changing. The transport sector is being electrified, and new types of consumption are emerging, such as data centres and battery factories. Smart meters enable more efficient data collection, providing new opportunities. Renewable energy sources, like solar and wind, may present challenges but can also contribute to effective power system operations.

Better utilisation of the grid
Flexibility can be a cost-effective alternative while waiting for new grid infrastructure to be built. The grid must be utilised better than it is today, which can be achieved by consumption management, energy storage, and smarter control of distributed power generation.

Batteries are becoming increasingly relevant for energy storage. While they remain more expensive than alternatives, costs are steadily decreasing, making them likely to play a larger role in the future.

Load Flow Calculations

Traditionally, load flow calculations analyse how power flows from the transmission grid to the regional grid, then to the distribution grid, and finally to the low-voltage grid. However, with the rise of renewable energy, flexible consumption, and batteries in the distribution grid, power often flows in the opposite direction; consumers become "prosumers." This reversal complicates the calculation of current flows and voltage variations in the grid.



Performance of the Battpower tool for memory efficient and high-performance multi-period AC optimal power flow solver, compared with MATPOWER Interior Point Solver (MIPS), for a test grid including Energy Storage Systems (ESS).

New tools are needed to account for local developments when analysing power flow. Emerging possibilities, such as consumption control and battery storage, actively influence voltage at a local level. To manage these resources effectively, it is necessary to consider the technical details of the power grid—this is where the concept of optimal load flow comes into play. Optimal load flow involves finding the best way to utilise local resources over multiple time periods. This requires solving a large mathematical optimisation problem that considers market prices, local flexibility options and grid constraints.

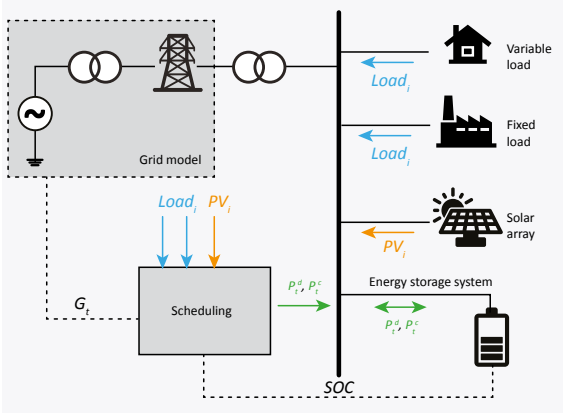
At CINELDI and in previous projects, we have developed several variants of optimal load flow with controllable units. We have reduced calculation times to a level suitable for practical use, making it a viable solution for those who are ready to adopt state-of-the-art grid analysis for active grids.

Three examples of results

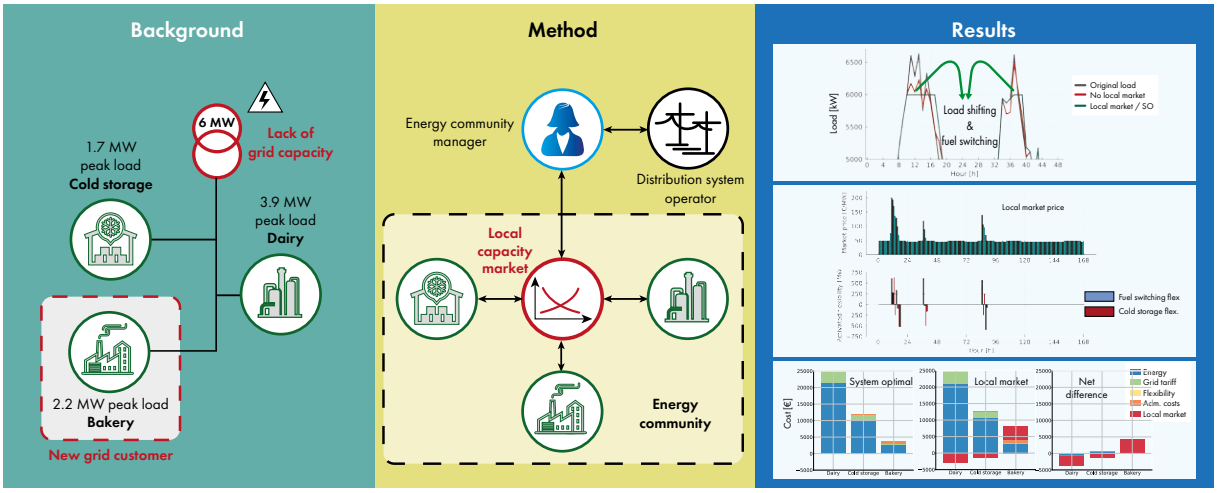
Flexible Loads as Services in the Power Grid

How can we utilise batteries and other flexible loads to provide multiple services to the power grid? This is where the concept of "value stacking" comes in. It refers to increasing the value of a battery by combining several services. For example, a battery can enhance solar power utilisation in the summer and serve as a power reserve in the winter.

At CINELDI, we have applied this concept to determine how flexible resources can be most effectively utilised across various markets. Should the resource focus on the spot market for maximum profit? Should part of its capacity be used for reserve markets to earn from balancing power? Or should capacity be held back to respond to signals from the grid operator that voltage needs to be boosted in a specific part of the grid?



Unlocking the potential of value stacking in Norwegian distributions systems, showing improved grid flexibility and stability through usage of multi-service Battery Energy Storage Systems (BESS). SOC = State of charge.



Enhancing grid hosting capacity with coordinated non-firm connections in industrial energy communities.

Coordination of Flexibility Among Actors in an Energy Community

An operational planning tool (see load flow calculations above) shows how to manage resources to meet all grid constraints and reduce operating costs—assuming a single actor controlling all units. In practice, however, resources such as power sources and consumption are owned by different actors with various agreements, such as connection agreements or specific grid tariffs.

How can these diverse actors, that share a grid connection point and its limitations, collaborate to find solutions to utilise the grid capacity in a better way?

We have developed various concepts for local coordinators who synchronise, for example, through a market solution. These concepts address how units are managed and how capacity can be traded between actors in the most cost-effective way while adhering to grid constraints. The goal is to approach system optimisation as closely as possible in practice. Although our work focused specifically on an industrial cluster, this approach is also applicable to neighbourhoods and microgrids.


Photo: Shutterstock

Reference grids, code, and data

Models of reference power grids, code for data analysis and measurement data have been crucial in most research activities within the CINELDI research centre.

Openness promotes collaboration, and at CINELDI, we have chosen to share code and datasets that may be relevant for other research scientists and students, both nationally and internationally. These resources are openly available online.

Norwegian reference grids

While many test grid models existed internationally, their accessibility — and not least, consistency in data descriptions — posed challenges for Norwegian conditions. Additionally, many international models are not representative of Norwegian power grids.

The reference grids CINELDI collected, along with associated load data, represent typical Norwegian distribution grids and load patterns, including scenarios for future development. They can be used to analyse historical and future load patterns, scenarios, flexibility needs in the power system, security of electricity supply, and reliability. The reference grids are also useful for grid planning, both with active measures and grid investments.

The base version of the reference grid, based on a real Norwegian distribution grid, can be adapted to incorporate overhead power line, underground cables or a mix of both, to identify the best option for a specific area. The model allows the integration of various flexible resources, cyber-physical networks with ICT infrastructure, and can be combined with low-voltage reference (LV) grids.

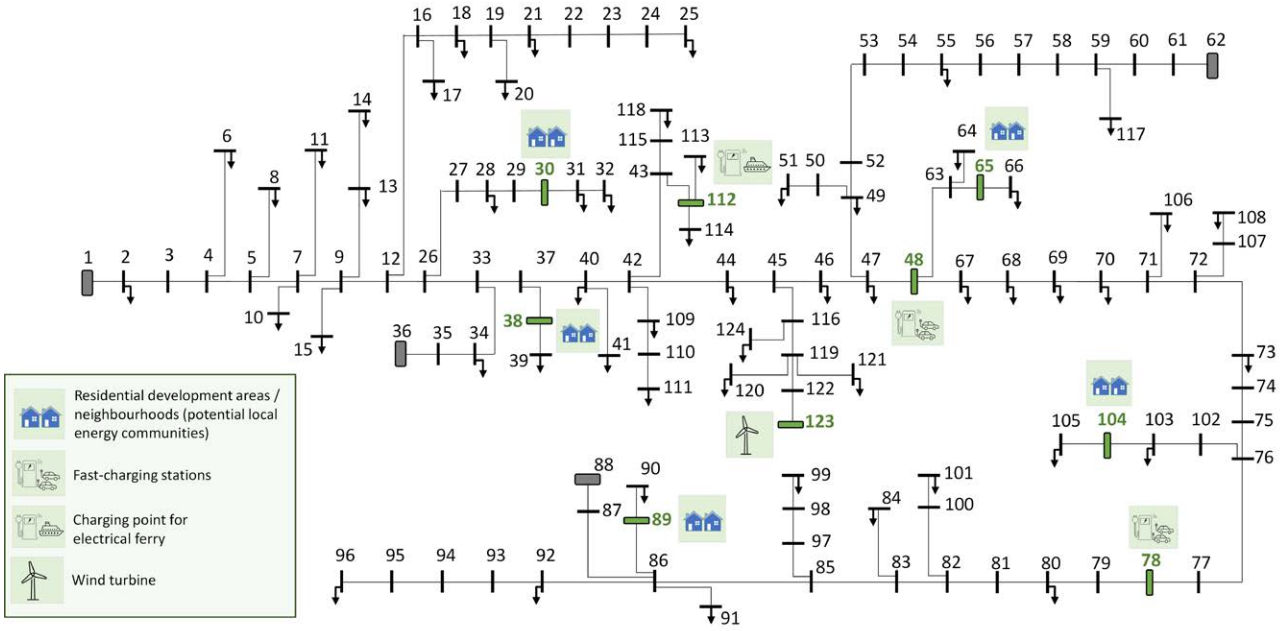
The figure illustrates how flexible resources have been integrated into the reference grid, representing future challenges and the benefits of flexibility introduced through local energy communities (LECs). These include fast-charging stations, ferry charging, and wind turbines. By experimenting with the placement of various resources, it is possible to investigate grid challenges and explore potential solutions.

Industrial distribution grid

At CINELDI, we also established a reference grid for an industrial distribution grid. This is based on a real Norwegian distribution grid and includes AMS data from 45 power consumers over three years. The grid comprises two radials interconnected by a backup connection. The dataset is complete with topology and electrical parameters. Both the grid model and data are openly available.

Data sharing

CINELDI's research is open, but in many cases, certain data must remain confidential to prevent the identification of individual power consumers. For this reason, customer IDs must be anonymised. Critical information about energy-sensitive infrastructure must also not be disclosed, and geographic names may sometimes need anonymisation.



CINELDI's MV distribution reference grid.

Code platform for flexible load analyses

CINELDI has developed a code platform for load analyses that aggregates consumption based on collected data and examines how this impacts the local distribution grid and the upstream grid.

The code platform was initially developed for load modelling and flexibility needs assessment in distribution grids by a student intern at SINTEF Energy Research and worked on a CINELDI pilot project. It was later expanded to analyse AMS data and test various approaches to load modelling for grid planning purposes.

The platform is modular and flexible, allowing new users to develop additional "building blocks" for the code without needing to understand all the other components. Users can also deactivate functions they are not interested in and adapt the code to their specific needs. The platform is equipped with a user interface that does not require advanced programming skills for basic analyses. The code can process historical data, assess flexibility needs in a grid, and perform "what-if" analyses.

Code platform for active distribution network planning

CINELDI has developed a code platform for planning active distribution networks. This platform uses an optimisation-based approach to grid planning that compares the following active measures alongside grid expansion:

1. Reactive power from fast-charging stations
2. Flexibility from local energy communities

The code demonstrates how active measures and grid expansion can address voltage issues in radial distribution grids. It also includes modules for socio-economic analysis and risk assessment of alternative grid development plans.

The platform was used to evaluate the economics of integrating fast-charging stations, to assess grid development strategies from a risk perspective, and to design incentives for leveraging flexibility from energy communities in grid operation.

Photo: Falkeblikk/Linja

CINELDI's pilot projects

The main goal of CINELDI's pilot projects was to test and verify technologies and solutions for the intelligent electricity distribution grid of the future.

CINELDI's 33 pilot projects were evenly distributed across four thematic areas:

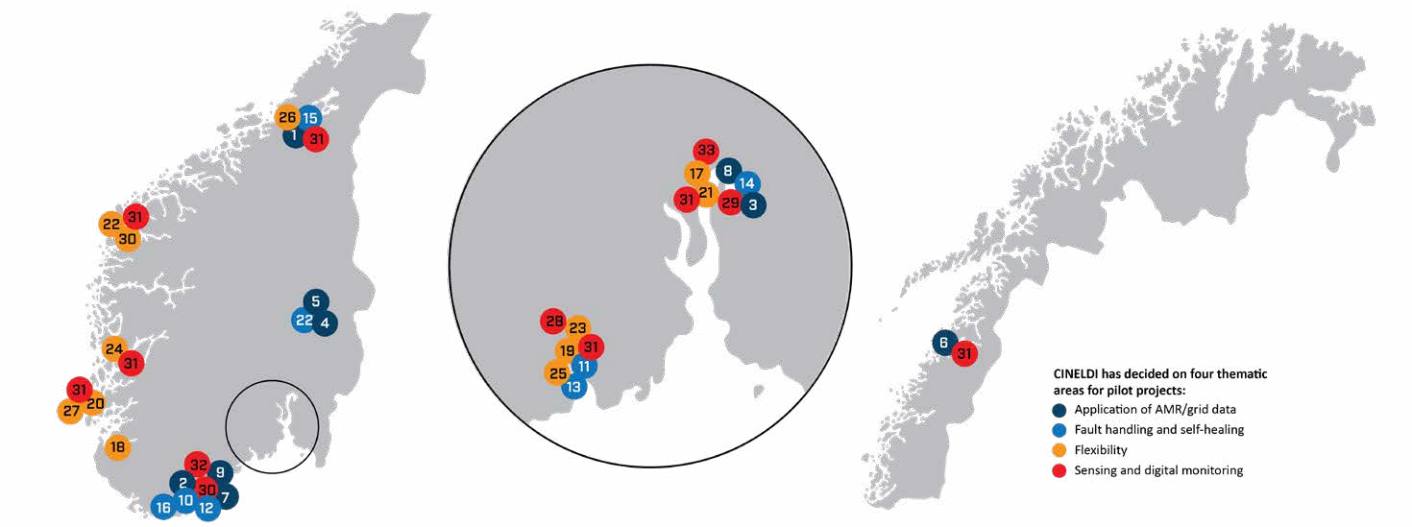
- Application of AMR/grid data
- Fault handling and self-healing
- Sensing and digital monitoring
- Flexibility

These thematic areas are important for grid companies and technology providers and are, of course, closely connected to CINELDI research.

Three examples of results

Large-Scale pilot projects

The pilot project "Flexible power grid by dynamic operation" brought together a technology supplier, research scientists, the Transmission system operator and several grid companies. They tested the use of Heimdall Power's neurons in various grids and cases. This pilot project resulted in several innovations. For example, Linja developed an integration setup for neuron data within the SCADA control system. This solution was adopted by BKK, another power grid company. Two other power grid companies had expressed interest in the set-up as the Centre concluded its activities in December 2024.



The map shows the geographical location of pilot project leads.

Three examples of results

Earth faults

One of the pilot projects focusing on earth faults was "Detection of earth faults based on data from smart meters". The grid has numerous standing earth faults, which is a typical Norwegian phenomenon due to the grid design that was selected. This problem must therefore be solved nationally, and at CINELDI, earth faults have been the focus of pilot projects with both Elvia and Lnett. Enhanced monitoring from smart meters provides more information, forming the basis for addressing these faults more effectively. Both the analysis work (locating the earth fault) and communication with consumers can be improved and made more efficient. Standardisation and automation are needed in this communication. Improvements in earth fault handling bring significant benefits to end users, including increased safety.

Three examples of results

Batteries in a smart grid

Batteries will become a key component in the future smart distribution grid. The pilot project Fast Frequency Reserve (FRR) tested how batteries can provide reserve capacity to the grid. With more wind and solar power, the Norwegian TSO Statnett will need more fast frequency reserve to maintain the power balance. This pilot project's test at Skagerak Energy Lab showed that the battery was successfully activated and fulfil the requirements to provide FFR. These results verified that FFR could be offered as a product from a large battery. The pilot project also resulted in a prototype of new functionality for activation and delivering FFR, which is now a commercially available solution.

Research Awards

CINELDI's research scientists actively organised and participated in international conferences, giving keynotes and acting as convenors and session chairs. Notable examples include the Probabilistic Methods Applied to Power Systems (PMAPS), the International Conference on The European Energy Marked (EEM), IEEE SmartGridComm, the CIGRE Paris Session, and CIRED Round Tables.

Best paper awards

Two CINELDI PhD students received international recognition for their papers in 2020. PhD candidate Kasper Thorvaldsen won the 2020 Roy Billinton Best Student Paper Gold Award at the PMAPS2 2020 conference. Associate PhD candidate Sigurd Bjarghov won the second-best paper award out of the 130 published papers at the EEM23-conference.

Santiago Sanchez-Acevedo with the best paper award.

A paper on voltage regulation, *"Cyber-Physical Distribution Power System for Assessing Voltage Regulation with State Estimator and Topology Identification in the Loop"*, by Santiago Sanchez-Acevedo et.al. received the best paper award during the smart grid session at the IEEE Industrial Electronics Society's conference in 2024.

Honorary Award for research on security of electricity supply

In 2020, Centre Director and Chief Scientist Gerd Kjølle received the Norwegian Academy of Technological Science's (NTVA) Honorary Award for her research on security of electricity supply. When Kjølle received the award, SINTEF CEO Alexandra Bech Gjørv stated that "her work has helped ensure a more cost-effective and sustainable power grid than before. SINTEF's mission is to create value for both industry and society. Kjølle's work is an excellent example of this".

Gerd Kjølle received NTVA's Honorary Award.

CHARGE Energy Award

SINTEF Energy Research won the prestigious CHARGE Energy Award for Best Organisation Brand in 2020, recognising excellence in energy branding and communication. The award-winning team, which also managed communication for CINELDI, was nominated partly due to their successful efforts in promoting CINELDI's work.

International cooperation

The FME period of eight years allowed for establishing long-term cooperation both nationally and internationally. From the start, in 2016, CINELDI was in a unique position internationally as one of the largest research centres in the field of smart grids, with major grid stakeholders being represented in the consortium. The Centre covered the most relevant research areas within smart grids and was a multidisciplinary organisation integrating the most important technology domains related to the topic. The Centre had access to unique research infrastructures: the National Smart Grid Laboratory infrastructure and living labs as part of pilot projects.

International cooperation enabled CINELDI to:

- Stay informed about emerging topics and promising methodologies under development
- Give CINELDI's research scientists access to the leading experts in their field
- Get access to laboratory resources not available in Norway and data from international demonstration projects
- Participate in international research projects
- Disseminate research results and build international visibility and recognition

Norwegian research partners were able to strengthen their international cooperation through the Centre, particularly in Europe. This was achieved by participating in international working groups and strategic forums, as well as attracting new EU-funded projects.

International cooperation was an integral part of the various Work Packages (WPs), focusing on specific research tasks. This collaboration included case studies, PhD research, idea and expertise exchange in workshops and seminars, joint publications, participation in international projects, and institutional partnerships at the PhD, postdoc, and guest researcher levels.

Participation in working groups and organisations

CINELDI research scientists participated in and led working groups and study committees in organisations such as IEEE ISGT Europe, AMC e-Energy, CIGRE, the CIRED, the ISGAN, and the IEA. These bodies are important for knowledge sharing, standardisation and innovation in the field of smart grids.

In 2022, ISGAN launched an International Knowledge Sharing Project titled *Network Planning and Decision-Making under Uncertainty*. CINELDI was represented in this project by one of our leading scientists, Iver Bakken Sperstad, who was appointed as a "Key National Stakeholder." One of CINELDI's research scientists participated in the IEA User Task Social License to Automate. Another example of such working groups is CIGRE WG C6.45: *The Impact of Distributed Energy Resources (DER) on the Resilience of Distribution Networks*.

Similarly, CINELDI scientists have strengthened their participation in the technology platform ETIP SNET and the European Energy Research Alliance (EERA). Within EERA, CINELDI has contributed to JP Smartgrids, SP Transmission, and SP Energy Storage.

Photo: SINTEF

CINELDI and ERIGrid 2.0's joint workshop in the National Smart Grid Laboratory in 2023 focused on automation in smart grids, the application of 5G technology and cybersecurity challenges.

CINELDI and the EU Horizon 2020 programme

CINELDI contributed to many project applications in the EU Horizon 2020 programme. Several of them were awarded funding. Examples are the H2020-projects FlexPlan, Erigrid 2.0, PAN-T-ERA and eNeuron. Additionally, CINELDI contributed to the ERA-Net project HONOR.

The FlexPlan project was linked to four of CINELDI's work packages. FlexPlan conducted a joint workshop with CINELDI, facilitated by our partner Renewables Norway. This workshop ensured that methods and tools developed in Europe, through the FlexPlan project, are made known to the Norwegian grid companies. Discussions and input from Norwegian actors at the workshop ensure that future case studies planned in FlexPlan will be applicable to the Norwegian power system.

In 2019 and 2023, CINELDI hosted a joint ERIGrid-CINELDI workshop on Smart Grid Laboratory development, in Trondheim. ERIGrid is an EU-H2020 project for research infrastructure.

In the China-Norway programme, CINELDI was part of the projects ChiNo-ZEN and KeyTech-NeVe-ChiNo – the latter via the KSP project FuChar. In 2023, a delegation from China visited Trondheim, marking ChiNo-ZEN first physical meeting. CINELDI has also collaborated with the projects ROME and MultiGrid, funded by the India-Norway programme, both dealing with microgrids.

CINELDI Conference: Future Electricity Distribution Grid R&D

In 2019, CINELDI hosted an international conference on Future Electricity Distribution Grid R&D. The conference began with an introduction on flexibility and communication from a CINELDI perspective. The conference had two main sessions, "Flexible resources to facilitate the smart grid transition" and "Smart grid communication and cybersecurity".

International webinar series

The CINELDI Conference on Future Electricity Distribution Grid R&D was initially intended as an annual international event. However, it was cancelled for three consecutive years due to COVID-19. To ensure

the continued dissemination of research results, the Centre launched an international webinar series in 2022. Consisting of five webinars, the series aimed to fulfil the conference's original objectives by increasing CINELDI's international visibility and relevance. By inviting distinguished researchers, the Centre fostered global engagement and knowledge exchange. Under the headline *"How can the distribution grid be adapted to facilitate large-scale electrification of society?"*, the webinars featured presentations from CINELDI research alongside international perspectives, followed by discussions and Q&A sessions.

International institutional cooperation

CINELDI's senior research scientists have served as opponents and taken part in examination committees in several international PhD defences in France, Belgium, Australia, India, the Netherlands and Denmark.

CINELDI and University of Cagliari collaborated on a Norwegian case study, using the SPREAD tool to plan active distribution grids. This was presented at a webinar for the consortium.

The Centre collaborated with MIT on markets for renewable energy and in the IEA Wind Task. Senior researchers and PhD candidates from CINELDI have had research stays at MIT.

A few guest research scientists, associate professors, and several PhD candidates from various countries have visited the Centre for stays ranging from one week to months. One of the WP-leaders spent a year on a research stay at MIT, and two PhD candidates undertook extended visits abroad. One of these visits was shortened by two months due to the outbreak of the pandemic. A planned research stay was also cancelled for the same reason.

In June 2023, the Scientific Committee (SC) gathered in Trondheim for a two-day workshop, with one or two PhD candidates from each member's institution also invited. CINELDI's WP leaders presented research and results, and the SC members outlined their work on relevant projects. The gathering provided insights and room for dialogue on common European issues. On the second day, PhD candidates and postdocs had their own workshop while the SC and WP leaders discussed a new FME application and work plans for the Centre's final period.

The Scientific Committee was gathered for a two-day workshop in 2023.

Training of researchers – CINELDI PhDs, postdocs and young researchers

PhD candidates and postdoctoral fellows

CINELDI had 30 PhDs and postdoctoral fellows (post-docs). 20 of these were fully or partially funded by the Centre. The remaining 10 were funded by closely integrated projects supported by the Research Council of Norway (RCN) or the EU H2020 programme.

The recruitment process focused on getting academically strong students who were motivated for both the field and the academic training position of a PhD. Half the candidates were Norwegian, which is a good balance given how hard it has been in the recent decade to recruit Norwegian students for PhDs.

The PhD candidates were actively involved in the work packages and consortium events. They regularly presented their results to partners through webinars and at consortium meetings.

CINELDI's specialised researcher training has included seminars led by senior research scientists. Examples of seminar topics include dissemination and best practices for publishing, interdisciplinary research, and innovation. The seminar on innovation was a joint event for PhDs and postdocs, organised by FME CINELDI and FME NorthWind. It was led by Ida Fuchs, Innovation Manager for electrification and digitalisation at NTNU's Department of Electric Energy.

PhD expertise in the workforce

The expertise and experience PhD candidates gain through their research are essential for driving innovation in their field. Throughout their PhD, they develop advanced research skills and deepen their subject knowledge, which they carry forward into their careers. This expertise benefits both the private and public sectors, contributing to the advancement of industry and academia alike.

PhD and postdoc seminar on innovation.

Employment of graduated PhD-candidates (number)							
By centre company	By other companies	By public organisations	By university	By research institute	Outside Norway	Other	Total
1	3		3	7			14

Mobility

The mobility of PhD candidates was impacted by the pandemic. Cancelled plans and a prolonged period of uncertainty limited the number of research stays abroad and with CINELDI partners. However, throughout the Centre period, many PhD candidates and postdocs participated in both short- and long-term research stays, both at international universities and with CINELDI partners.

PhD candidates affiliated with the experts in CINELDI's Scientific Committee participated in a two-day workshop in 2023.

CINELDI's PhD candidates conducted research stays at renowned institutions such the University of Helsinki in Finland, the Centre of Technological Innovation in Power Electronics and Drives (CITCEA-UPC) in Spain, MIT in the US, and École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland. For visiting researchers, CINELDI organised seminars where they could present their work to the Centre's research scientists.

The analyses and research conducted by PhD candidates often address specific local challenges. A large share of CINELDI's work is focused on the Norwegian power system, but some projects also involve extensive collaboration with international partners. Such interactions, particularly in forums with multiple international participants, are crucial for gaining a broader and more nuanced understanding of global challenges.

Photo: Geir Mogen/NTNU

In 2023, we expanded CINELDI's Scientific Committee (SC) gathering to include a workshop for PhD candidates and postdocs. The SC members brought along PhD candidates from their institutions to this event to meet some of CINELDI's PhD candidates. During this workshop, research scientists and PhD candidates presented studies on the future of power systems in countries such as Italy, the Netherlands, and Denmark. The discussions offered valuable insights into the diverse challenges facing power systems worldwide.

150 master's students

Master's theses were an important contribution to CINELDI, and the Centre had many excellent master's candidates working on relevant research topics, making valuable contributions to the research field.

CINELDI's research scientists at NTNU have taught and supervised students, while scientists at SINTEF Energy Research and SINTEF Digital have also been involved in supervising and teaching students. Additionally, SINTEF scientists have regularly delivered guest lectures at both NTNU and the University of Oslo (UiO).

Relevant work from master's theses has been presented in webinars and blogs and added to the CINELDI Knowledge Base. After completing their studies, CINELDI's master's candidates have brought the Centre's up-to-date, specialised knowledge into both industry and academia. Many candidates have also published articles based on their thesis, in collaboration with their supervisors. Additionally, final-year master's students have been invited to participate in the open CINELDI Days and the CINELDI Final Conference.

As a recruitment measure, CINELDI participated in SINTEF Energy Research's summer scientist programme. Some of CINELDI's pilot projects formed the basis for student assignments. The students gained both relevant professional expertise and an insight into working as a scientist, and the Centre received valuable results in return.

New study programme

In 2021, NTNU launched a new bachelor's degree programme: Electrification and Digitalisation (ELDIG). This programme has been further developed into a master's degree. Scientists at CINELDI have contributed to both of these initiatives.

Sigurd Bjarghov

Current position: Research scientist at SINTEF Energy Research

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

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

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

Outi Pitkänen

Current position: Post-doctoral researcher at Helsinki University, Centre for Consumer Society Research

PhD Thesis: *The loads that connect us: how Norwegian actors work to produce flexible electricity consumption*

I am currently working on a research project on end-user flexibility in Finland, where the project's focus is on consumers who are vulnerable to energy poverty. This is an interdisciplinary collaboration that combines approaches from political science, engineering, social sciences and economics. Having done my PhD at CINELDI, I am familiar with how different disciplines approach end-user flexibility and what technical intricacies need to be solved to scale up end-user flexibility. Moreover, I appreciated that participating in CINELDI events gave me an understanding of the technical debates related to end-user flexibility.

I wanted to understand end-user flexibility as a phenomenon that results from the joint efforts of professionals and electricity users. Being affiliated to CINELDI enabled me to understand the innovation networks' work to increase flexibility in the grid on the one hand, and what electricity users' understandings of flexibility or their work to consume flexibly are actually like, on the other hand. Recruiting relevant actors for interviews was relatively easy and thanks to CINELDI's facilitation, I got to do a two-week research stay at a grid company, which greatly benefited my thesis.

Fredrik Göthner

Current Position: Senior Engineer at Siemens Energy and Associate professor II at the University of Stavanger

PhD Thesis: Stability and Power Quality Improvements to Facilitate Wide-Scale Deployment of Future Microgrids

I am lucky enough that I can apply many of the concepts and skills I acquired during my PhD in my current job at Siemens Energy. Besides specific skills within modelling and control of power systems, I've also learned about adjacent topics, through CINELDI, that are relevant in my current job. One of the great points with research centres in that sense is their ability of covering both the big picture as well as the details.

I am motivated by working with solutions for a more sustainable future, which is exactly what CINELDI could offer through research on microgrids. The Centre also offered a much larger community for getting feedback and inspiration, which I likely would not have had otherwise.

Photo: Shutterstock

Communication and popular dissemination of knowledge

When the Centre was established in 2016, the power grid was not a topic that received much attention or discussion. In recent years, however, the power grid has become a subject of greater interest to both authorities and the public. The extensive work of CINELDI's partners in addressing issues related to the power grid may have contributed to this increased focus. Additionally, the topic has naturally gained attention as these issues have become more visible over time, increasingly impacting people, businesses, and policymakers.

A knowledge hub

CINELDI maintained a prominent presence in the industry. The Centre'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.

CINELDI was recognised as a knowledge hub for research on the power grid, and its research scientists were highly demanded as presenters at conferences and events in both academia and industry.

FME Conference to Tackle Climate and Energy Challenges

CINELDI participated in the Centres for Environment-friendly Energy Research (FME) Conference in 2024. The conference featured high-impact dialogue and interdisciplinary exchange, focusing on the critical role of FMEs in addressing climate and energy challenges. The session "The Flexible Integrated Energy System" was organised by CINELDI and NTRANS.

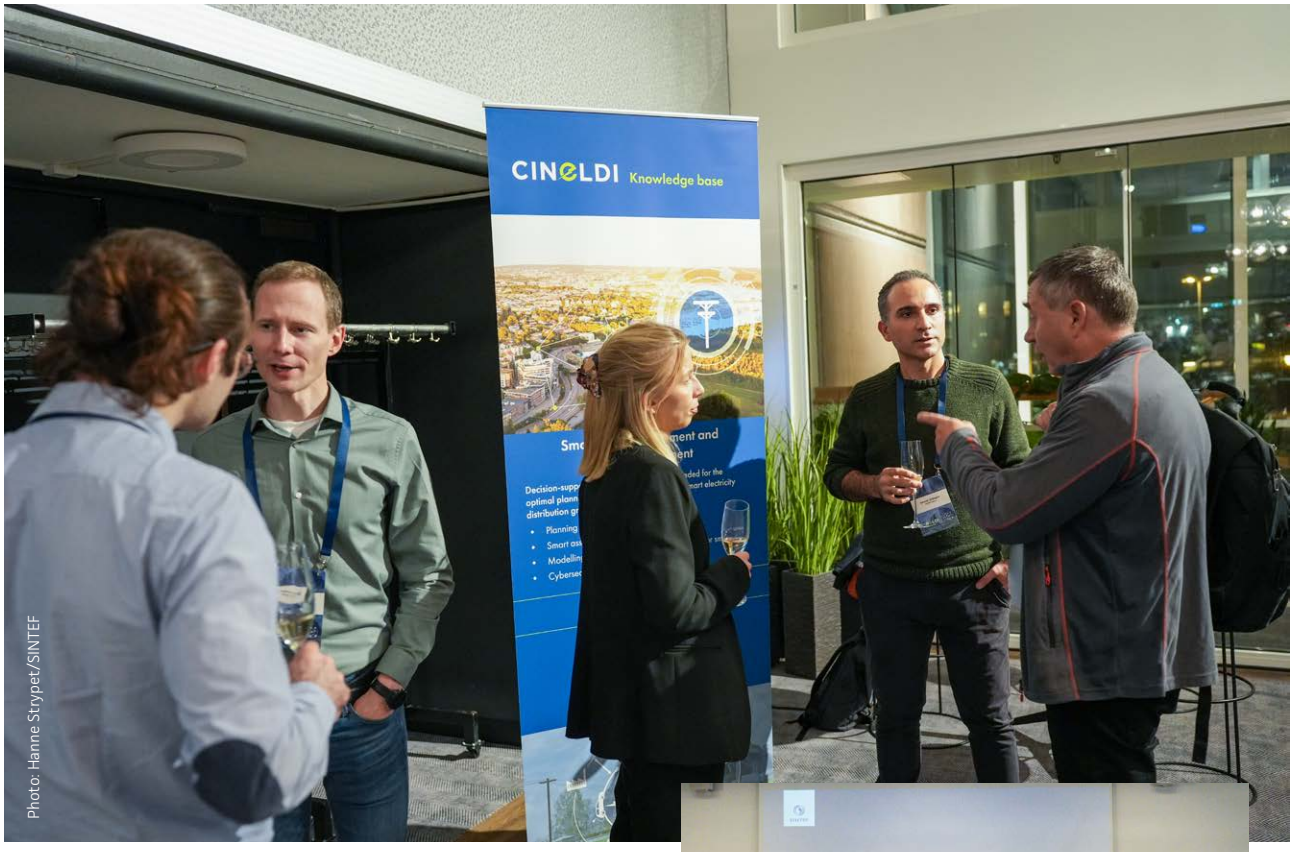
CINELDI conferences

The Centre also organised its own conferences in 2019, 2022 and 2023, in addition to hosting a final conference in November 2024. Webinars, both national and international, have also been an important channel for sharing the Centre's results.

The Minister of Energy, Terje Aasland, opened the final conference by stating, "This is the beginning".

Panel discussion at the final conference. Left to right: Atle Harby (SINTEF), Bernhard Kvaal (Aneo), Kristin H. Lind (Renewables Norway), Terje Aasland (Minister of Energy), and Eirin Kjølstad (Arva).

Panel discussion at the final conference. Left to right: Gaute Haaversen-Westhassel (Tibber), Hallstein Hagen (NODES), Martha Marie Øberg (Statnett), Magnus Korpås (NTNU) and Anne Sagstuen Nysæther (Elvia).



Each of the six themes in the knowledge base was presented at the final conference. Here, Iver Bakken Sperstad, Susanne Sandell, and Gencer Erdogan share results from Smart grid development and asset management.

Knowledge base, news media, and LinkedIn

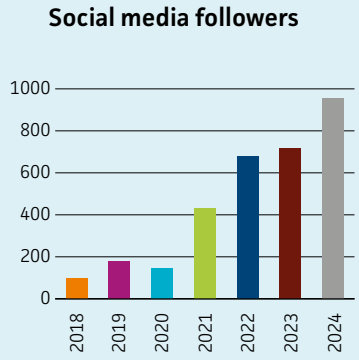
CINELDI has employed various methods to broadly communicate its results. The Centre's website serves as an important resource for providing access to outcomes. The results have been collected and organised in a knowledge base, making it easy for external users to locate specific findings. The website and knowledge base will remain available beyond the Centre's lifespan.

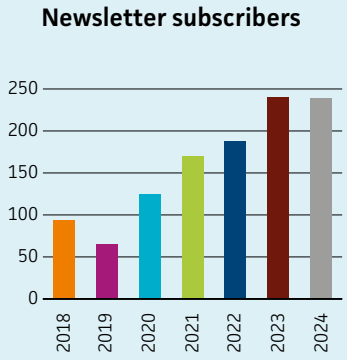
Research scientists and some of the user partners have been active in sharing results through blog posts, opinion pieces, and appearances in the media, in both industry-specific and general news outlets. LinkedIn and newsletters have also been key channels for engaging with diverse target groups.

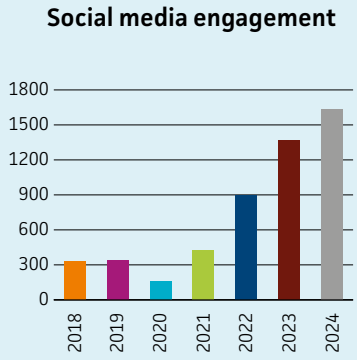
Arendalsuka 2024. Left to right: Anders Lie Brenna (moderator), Therese Åsheim (Heimdall Power), Anne Nysæther (Elvia), Ingeborg Øfsthus (Statnett) and Tore Langset (RME-NVE).

Political festival and policy briefs

CINELDI participated in events at Arendalsuka, Norway's largest political festival, in 2022, 2023, and 2024, to raise awareness about the challenges the electricity grid will face in the coming years and potential solutions to address them. The Centre has also contributed to policy briefs, reports and position papers.

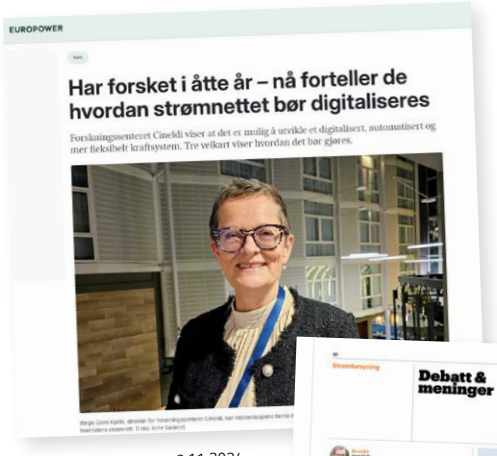






Popular science video

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 was used in communicating the Centre's work, both through digital channels and at events.


EUROPOWER

Har forsket i åtte år – nå forteller de hvordan strømnettet bør digitaliseres

Forskningssenteret Cineldi viser at det er mulig å utvikle et digitalisert, automatisert og mer fleksibelt kraftsystem. Tre veikart viser hvordan det bør gjøres.

Facsimile, Europower 6.11.2024


Strømforsyning

Debatt & meninger

Ekstremvær, cyberangrep og elektrifisering: Er Norge rustet for fremtiden?

Facsimile, op-ed in Aftenposten 11.7.2024.

Media contribution:

188

Op-eds:

18

Blogs and information material:

130

Effects of Centre for the host institution and research partners

"For SINTEF Energy Research, hosting a frontier research initiative like CINELDI has been both an honour and a unique opportunity to drive forward world-leading research."

- Inge Gran, CEO,
SINTEF Energy Research

CINELDI established a strong platform for strategic, long-term research and collaboration on the future grid. The Centre's work led to a better national structure for smart grids research and increased research activity within the field at the host institution, SINTEF Energy Research.

Effects on the host institution's research strategy

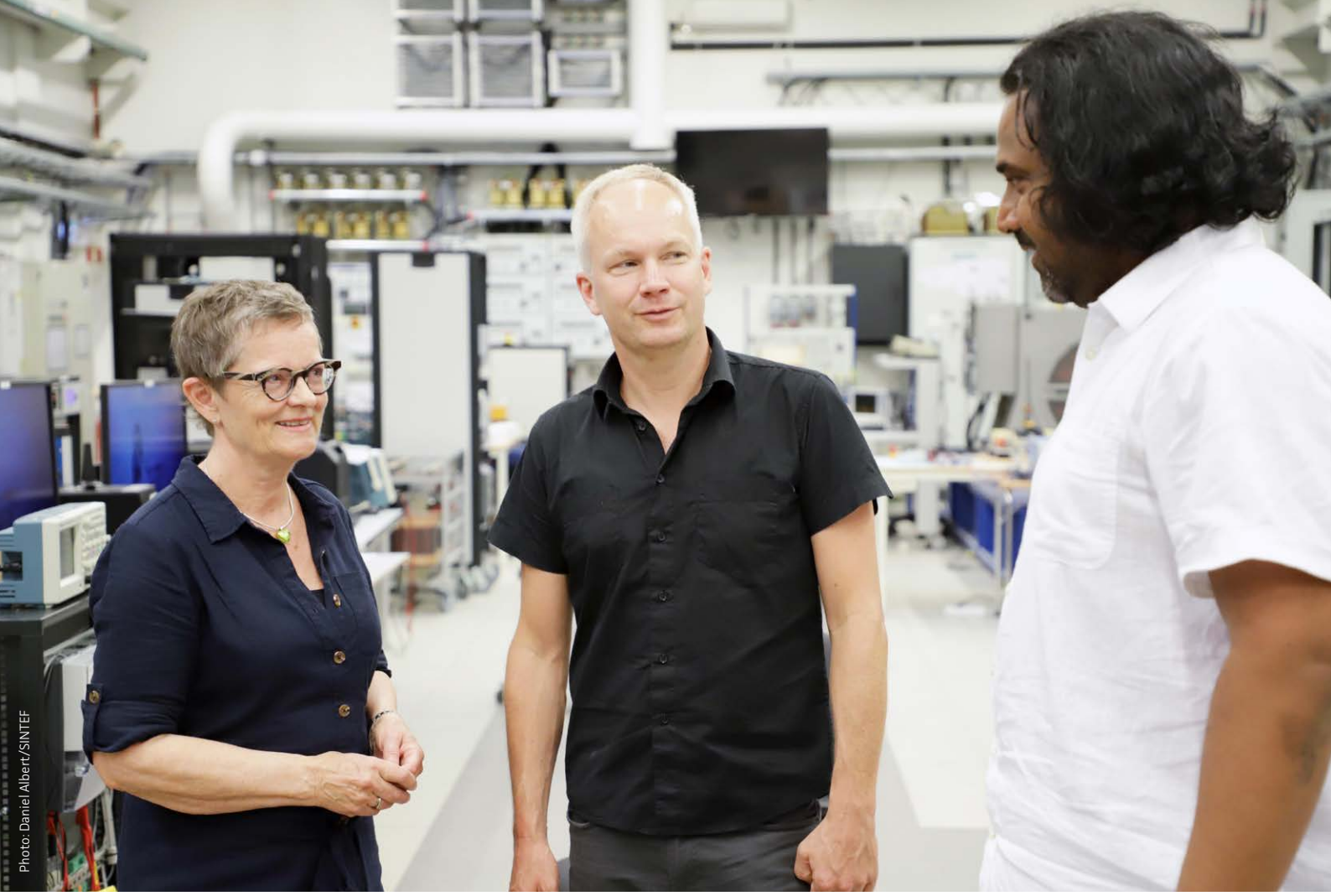
SINTEF Energy Research's mission is to shape the energy solutions of the future. CINELDI's goals and mission align closely with SINTEF Energy Research's strategic areas renewable energy, decarbonised energy and future energy system, and the prioritised research area Smart Grids. The Centre has played a key role in advancing the host institution's research strategy on smart grids.

CINELDI has worked on topics such as digitalised, cost-efficient and flexible electricity distribution grids, increased integration of renewable power generation, electrification of transport, more efficient use of power and energy, and ensuring a high security of electricity supply. Through this work, the Centre has contributed to new and important knowledge in these fields which can be implemented by the industry and expanded on in further research, both within SINTEF and other research institutions.

The Centre's research activities culminated in the forming of a strategy and road map for the transition of the Norwegian power grid to becoming a flexible, intelligent power grid for the future. This transition strategy will be integrated into future activities. SINTEF Energy Research recently approved a revised research strategy, and the plans for the prioritised research area Smart Grids are currently being updated to align with the CINELDI transition strategy and roadmap.

For SINTEF Energy Research, the FME scheme is an important instrument to increase interaction and collaboration among R&D and user partners. Its long-term perspective provided a strong foundation for developing knowledge and building research capacity within the topics of interest. It has also served as an important arena for meeting and exchanging knowledge and information. In this way, CINELDI has paved the way for spin-off projects, both with user partners involved in the Centre and other collaborators.

CINELDI's extensive collaboration with the university sector – with the Norwegian University of Science and Technology (NTNU) especially – has been of great importance to SINTEF. The host institution has strategically worked towards the goal of contributing to the education of MSc, PhD and postdoctoral candidates, both to strengthen the internal academic level and to support the development of a stronger academic sector. Several skilled research scientists who obtained their PhDs within CINELDI have been recruited by SINTEF Energy Research, where they have continued working on relevant topics, both within the Centre and through other projects.



The facilities of The National Smart Grid Laboratory have been important in achieving many of CINELDI's results. Form left to right: Gerd Kjølle (SINTEF Energy research), Magnus Korpås (NTNU) and Vijay Vadlamudi (NTNU).

CINELDI developed valuable knowledge and partnerships, and established national and international networks. Moving forward, these will contribute to long-term national expertise building and system innovations, which are crucial for achieving energy and climate goals through electrification.

Effects of Centre for the research partners

Collaboration within CINELDI has strengthen ties between the three research partners and with the user partners across the Centre's various fields of research. The multidisciplinary platform of research, laboratory work and pilot projects facilitated the cooperation.

NTNU

As a nationally leading university, NTNU has a societal responsibility to pave the way for an electrified and net zero-emission society. Energy is one of NTNU's key strategic research areas, and through CINELDI, the university has had the opportunity to enhance its disciplinary and interdisciplinary collaborative research efforts in the field of smart grids.

CINELDI helped substantially increasing knowledge and expertise within NTNU on smart grid-related challenges and opportunities. CINELDI's multidisciplinary research platform for realising cost-efficient solutions for intelligent electricity distribution systems brought together research scientists from different departments and faculties at the university, fostering closer collaboration and

providing increased insight to scientists and educators across their own disciplines.

NTNU has supervised 23 doctoral candidates in and in relation to the Centre. These candidates have contributed to answering key research questions, and form a pool of highly skilled professionals.

CINELDI's work has created new opportunities to widen and improve NTNU's educational offers at all levels, increasing the teaching capacity, and raising the domestic base of interdisciplinary experts. Centre activities on smart distribution grids have attracted new students, stimulating recruitment at NTNU, especially in the three-year bachelor's study programme *Electrification and Digitalisation* (ELDIG) and the five-year integrated master's study programme *Energy and the Environment*. Of particular note is the Centre's role in the conception and execution of ELDIG.

NTNU's participation in CINELDI has provided the university with an opportunity to exert influence on the research agenda in the electricity sector in Norway, in close dialogue with industry and politicians.

SINTEF Digital

SINTEF Digital's scope of research is broadly focused on developing enabling technologies for industrial challenges. Through CINELDI, SINTEF Digital's research scientists have had the opportunity to work closely with power grid companies and technology providers to identify some of the most important technological challenges facing the industry. CINELDI provided an opportunity to apply research to relevant grid company challenges in fields such as distributed real-time systems, communication technologies, cyber security, and estimation and control. These challenges help shape relevant research topics when applying for fundamental research funding.

The research collaboration between SINTEF Energy Research and SINTEF Digital has been strengthened in several research areas e.g. in cyber security and estimation and control. Participating in a centre like CINELDI has given SINTEF Digital scientists access to lab facilities and real time data to test research results in close cooperation with advanced technology companies and end users.

Sture Holmstrøm in SINTEF Digital presenting at the final conference.

Effects of Centre for the company partners, public partners and society at large

The Centre served as a collaborative arena for a wide range of stakeholders, bringing together research scientists and partners from all parts of the industry.

The three-party cooperation between technology providers, DSOs and scientists was important for CINELDI and led to the sharing of best practices as well as a faster implementation of new technology. Together, participants discussed various challenges and developed new solutions that benefit not only the partners but also society – by enabling power grid companies to operate more efficiently and optimise their capacity, for instance. The twelve DSO partners of CINELDI cover about two thirds of the total Norwegian end users. The national knowledge building carried out by this range of companies has the potential to significantly impact the power sector. Not everything can be solved in an FME, but an FME is fantastic for gaining an overview and structuring research and piloting. It also serves as a platform for long-term collaboration between research and industry within a large area such as the future power grid.

From the final conference, where some of the board members discussed how to implement the strategy and roadmap. From left to right: Moderator Ruth Astrid Sæter, Anngjerd Pleym (NTNU), Ingvill Stenseth (BKK), Per-Oddvar Osland (Glitre Nett), Bjørn Harald Bakken (Statnett), Knut Samdal (SINTEF Energy Research), Espen Kåsin (Embriq) and Hermund Slaatsveen (Aidon Norge).

Collaborative efforts

CINELDI began with a large collaborative effort involving all partners to 1) identify the driving forces for intelligent electricity distribution system innovation and 2) develop scenarios for the electrical distribution grid in 2030–2040. This resulted in several reports. CINELDI partners highlighted this work as important during the midterm evaluation, noting its influence in shaping and guiding their individual R&D innovation strategies.

Working alongside expert personnel and research scientists, partners also shifted their perspective on participating in joint innovation and R&D, as well as using published research. The collaborative work done in workshops also helped establish a solid network between the various user partners' representatives for collaboration both within and outside the Centre. The work continued during the Centre's final two years, culminating in the development of CINELDI's strategy and roadmap for transitioning to a flexible and intelligent power grid, providing a clear direction and unified message to the industry, policymakers and society.

CINELDI's most important effects

The DSOs have highlighted the Centre's importance both as a platform for discussion and as an arena for collaboration on pilot projects. CINELDI has been a catalyst in the industry, creating a fruitful environment for innovation and development.

The technology providers highlight that CINELDI has given them the opportunity to connect with the market for their solutions. NODES, Heimdall Power and Disruptive have all expanded the adoption of their technology. Additionally, Disruptive reported that insights gained from the Norwegian energy sector facilitated their entry into international markets. CINELDI cannot take full credit for the expansion of these companies, but the Centre certainly has contributed to their development.

Pilot projects, along with the collaborative platform provided by an FME, offer significant value to technology suppliers. A centre like CINELDI serves as an important arena for generating ideas for new product development.

Over the past two years, the industry – particularly power grid companies and Statnett – has shown clear maturation. During this time, they have significantly increased their readiness to implement 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, and self-healing grids.

Building the smart, flexible, robust grid of tomorrow in a cost-effective way requires a major effort from all parts of the industry: from authorities setting the regulatory framework, to the TSO and DSOs operating the grid within it, and everyone in between. CINELDI is proud to have been an active consortium with partners putting in hard work and dedication towards joint goals.

The full results and effects of CINELDI's research have not yet been fully measured, as much of the research will be applied in years to come.

Photo: Ingvild S. Aursland/SINTEF

CINELDI workshops have brought all partners together for joint discussions.

Knowledge building

CINELDI's results have been made available in a knowledge base to facilitate their adoption. New knowledge from research and pilot projects has been shared among partners throughout the process and is now openly accessible. In the last two years of the Centre, dissemination measures targeted at the sector were prioritised with both an international and a national webinar series, and open invitations to the annual CINELDI Days event.

Through the education of over 150 master's students and 30 PhD and postdoctoral candidates, the industry has gained access to qualified personnel. The Centre also had a doctoral project in industry, where one of Statnett's employees completed a PhD at NTNU. An industrial PhD project gives the company employee specialised expertise and researcher training, and the company gets results on a topic on which they need more insight.

Photo: Falkeblikk/Linja

Success stories

Flexible power grid by dynamic operation

This large-scale pilot project involved eight of the Centre's user partners. It has provided the user partners with valuable results in the form of technological improvements, better decision-making foundations, new collaborations, and innovations in work processes. The experiences from this pilot project shows that the partnership has contributed to more efficient and data-driven grid operations, benefiting both grid companies and end-users.

- Several power grid companies identified and demonstrated how Dynamic Line Rating (DLR) can be used to optimise the existing grid's capacity without costly expansions.
- The DSO Linja developed a solution that simplifies the integration between the Heimdall Power Cloud API and SCADA systems, providing grid companies with more seamless and efficient operations.
- The DSO Fagne demonstrated how monitoring specific limiting spans can offer a far more accurate measure of the actual transmission capacity of a line, compared to theoretical assumptions..
- Heimdall Power further developed drone installation of Neurons, and this method is now the primary installation approach both in Norway and internationally.

Advanced detection of earth faults

Through testing at the National Smart Grid Laboratory, Aidon obtained a solid data foundation for developing a solution to handle earth faults automatically. Aidon is a leading supplier of smart meters (AMS) in Norway. Testing Aidon's earth fault solution in a real power grid would have been both impractical and hazardous. However, the laboratory enables the setup of a safe test environment that can simulate a real power grid.

Changed work processes

CINELDI had a clear goal that all pilot projects should be useful to more than just the participating partners. As a centre where key stakeholders are government-regulated monopolies, there are fewer barriers to openly sharing results, such as new and improved work processes. 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.

Algorithms – developed and tested – new integrations to maintenance systems, and new frameworks for Energy Management System (EMS) are examples of results from pilot projects shared and discussed between the partners.

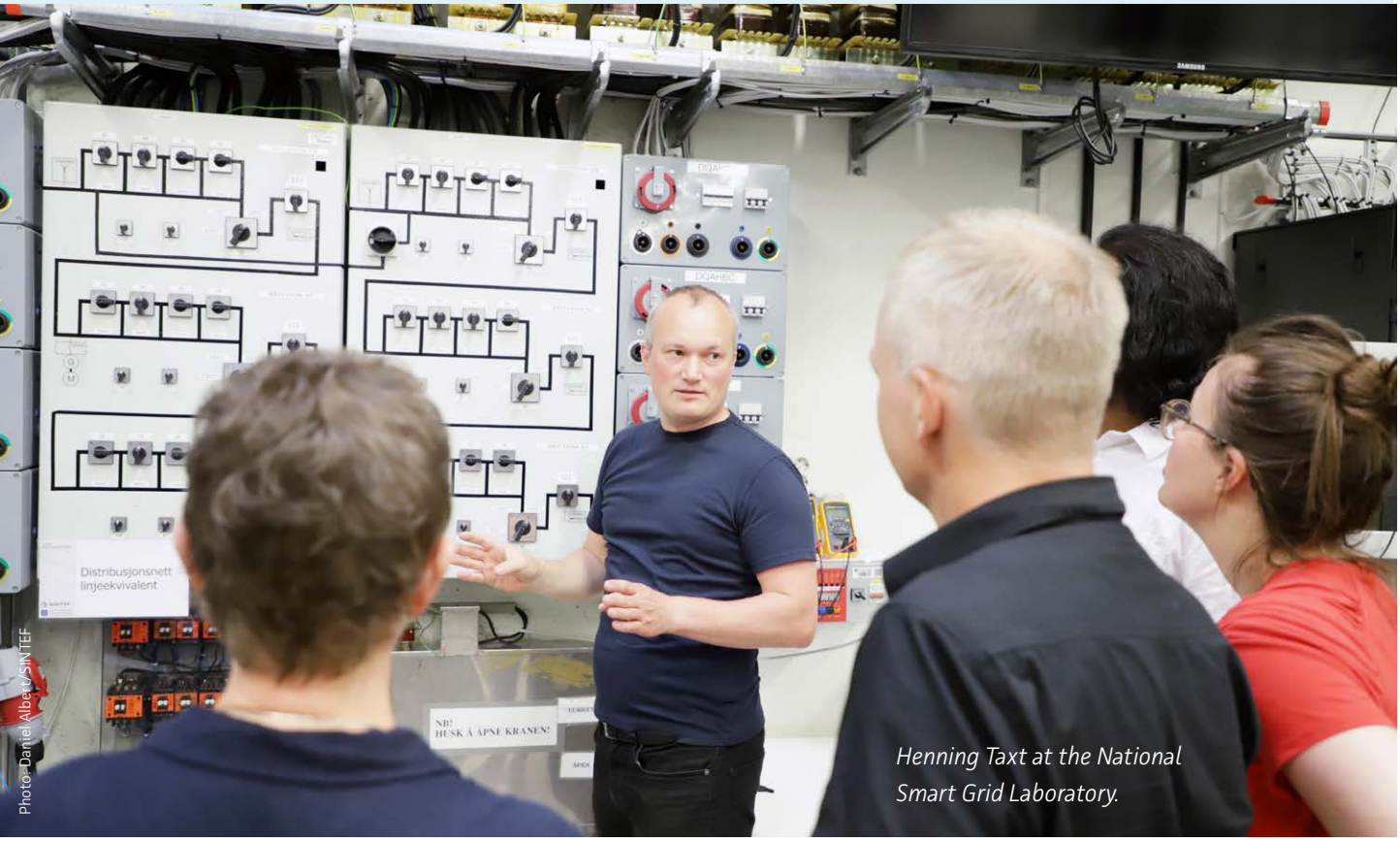


Photo: Daniel Albert/SINTEF

Henning Taxt at the National Smart Grid Laboratory.

From the user partners

Per-Oddvar Osland

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

Gunnar Vist

For us, it is this three-party cooperation that is important; the technology providers, the DSOs - the companies that are actually going to use the product – and the scientists. This is the way to actually make innovation work. Heimdall Power joined CINELDI in 2019, and through a large-scale pilot project in the Centre, we had the opportunity to test our sensor – the neuron – in a system perspective.

Gunnar Vist, Heimdall Power

Sigurd Kvistad

At Elvia, we have restructured how we follow up on R&D projects based on our experiences from CINELDI. We realised that, as a grid company, we were not adequately set up to fully benefit from participating in research and development projects. Therefore, we no longer join new projects unless we have dedicated resources within the organisation to follow them up.

For the new research centre, FME SecurEL, we established an internal steering group to ensure that Elvia gains the greatest possible value through active participation and competence building.

Sigurd Kvistad, Elvia, Chair of the CINELDI Board.

Sven Arild Kjerpeset

Research and innovation are one thing, but integrating the results and solutions into day-to-day operations is just as important. At Linja, we have worked hard to understand how new ways of thinking affect individual employees in their daily routines. One of the reasons we succeeded with the Heimdall pilot is that we embedded it throughout the organisation, particularly among our operations engineers who gained access to better data and new ways of working.

Sven Arild Kjerpeset, Linja

Jun Elin Wiik

In a changing world, modernising the power system is more important than ever. Achieving this requires research and collaboration across the entire value chain. CINELDI has been a key meeting point where industry and research scientists come together for productive discussions about researching and developing much-needed solutions.

Jun Elin Wiik, The Norwegian Smart Grid Centre

Research and pilot projects in CINELDI have contributed to 50 innovations. All of these are described in this report.

Analysis of the role of the Centre

When CINELDI was launched in 2016, the power grid was taken for granted and simply seen as an underlying necessity. There were not many news stories about new electricity consumers being unable to connect due to capacity constraints. Over these eight years, the power grid has moved from the 'shadows' to being recognised as a crucial factor for enabling the green transition and value creation.

In many countries across Europe and the rest of the world, strategies and roadmaps for smart grids had already been developed in 2016. Norway had neither such a strategy nor a roadmap, but there was a shared understanding among research scientists and the industry that research, innovation, and new expertise were necessary to meet future challenges—especially for the distribution grid, which was and still is the least intelligent part of the power system.

Digitalisation and electrification

Over the past eight years, we have witnessed rapid technological advancements in areas such as sensors, 5G communications technology, drones, batteries, power electronics, and IT tools. These developments have created new opportunities that CINELDI has researched. The digitalisation of the distribution grid began with the rollout of smart meters (AMS) for all Norwegian consumers in 2019. This has provided access to vast amounts of new data—data we must utilise. However, digitalisation also brings challenges, particularly in terms of cybersecurity.

During CINELDI's years of activity, shifting social attitudes, evolving values, and declining public acceptance have become even more prominent drivers—as resistance to wind energy development has grown, along with opposition to many aspects of grid expansion and increased power production.

With accelerating climate change, electrification has become even more urgent. In turn, this creates a pressing need to utilise existing grids more efficiently. 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 encroachment on nature. These developments over CINELDI's eight years of activity have made the Centre even more relevant.

The COVID-19 pandemic

The pandemic affected the Centre through less mobility between academia and industry and less international cooperation than was initially planned.

The energy situation in Europe

The energy crisis in Europe, soaring electricity prices in Norway, and Russia's invasion of Ukraine have underscored geopolitics as a profound and lasting factor impacting the power grid.

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 growing need for power grid solutions that support electrification while maintaining security of supply is increasingly evident.

A sustainable power grid is environmentally friendly, reliable, and cost-effective—this energy trilemma has been a key focus throughout CINELDI.

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 create 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 was further strengthened by RePowerEU: affordable, secure, and sustainable energy for Europe, which is the EU's plan to accelerate Europe's green transition and end the region's dependency on fossil energy from Russia. The plan includes increased renewable power generation, increased efficiency in both power and energy, and increased electrification.

Building capacity and strengthening collaboration in the power grid sector

In the Centre's early years, research and development within power grid companies was limited. Collaboration in a large research centre with other power grid companies, technology providers, and research scientists was a new experience for many, despite experience with smaller research projects. Over time, grid companies have adapted their workflows and structures to better adopt and implement new solutions.

Collaboration on new solutions has contributed to the development of grid operations and increased standardisation in the industry, benefiting power grid companies, the TSO, and technology providers alike. Through research and pilot projects, the Centre has built expertise among power grid companies, technology providers, and regulatory authorities, equipping these stakeholders to face future challenges.

Norwegian stakeholders have strengthened their internal capabilities in development and innovation. For technology providers, the Centre has helped open larger markets both nationally and internationally. For example, NODES, Heimdall Power and Disruptive have expanded the adoption of their technologies.

For the research community, CINELDI has demonstrated the relevance of Norwegian research beyond national borders. Internationally, research on distribution grids has been limited, making CINELDI's contributions to research and development in this field unique.

All PhD projects conducted within or in connection with the Centre have contributed to training a new generation of researchers and strengthening research environments on this topic among the three research partners. This has also paved the way for the new FME SecurEL research centre and other projects, including Knowledge-building projects (KSP), Innovation projects (IPN), Green Platform and Pilot-E projects.

Future prospects

FME SecurEL's Centre Management group. Left to right, front row: Ida Sortland (Centre coordinator), Camilla Espedal (WP3 Lead), Gerd Kjølle (Centre director), Kari Espegren (WP4 Lead) and Maren Istad (WP5 Lead and Pilot project coordinator). Backrow, left to right: Vijay Venu Vadlamudi (WP1 Lead), Oddbjørn Gjerde (WP2 Lead) and Henning Taxt (WP6 Lead and Innovation leader).

Continuing with SecurEL

CINELDI outcomes will be carried forward through SecurEL, a new Centre for Environment-Friendly Energy Research. SecurEL places a greater emphasis on security of electricity supply. The ambition is to enable the electrification needed to achieve climate goals while safeguarding the security of electricity supply. Most of CINELDI's partners are participating in the new Centre, along with new research and user partners.

Through CINELDI, user partners have gained expertise in how to utilise research and apply its results. User partners have developed closer relationships with the research community through collaboration within the Centre. Interdisciplinary knowledge has increased across all partners. The three-party cooperation between the technology providers, the DSOs and the scientists continue as a key feature of SecurEL.

Spin-off and employment of results

PhD candidates with a connection to CINELDI have been employed as research scientists at SINTEF Energy Research and other research institutes. CINELDI contributed to structuring research within the Centre's thematic area. Through the Centre's period of activity, research scientists from the host institution and research partners have developed expertise across CINELDI's research fields and in related disciplines, continuing their research in other projects focused on optimising grid utilisation.

CINELDI spin-off projects address topics such as local energy communities, the implementation and development of charging infrastructure for electric vehicles, forecasting future load demand, and automated grid operation. CINELDI has contributed to new research, innovation and competence building projects across the entire TRL scale. About 50 potential innovations are described based on the research and pilot projects, categorised by type and estimated TRL. Four of these are commercial solutions.

Many of CINELDI's user partners have begun incorporating the Centre's strategy and roadmap for transitioning to a flexible and intelligent electricity grid into their own company strategies and implementation plans.

Continuing lab setup

The lab setups developed in The National Smart Grid Laboratory through CINELDI will be continued. This includes the collaboration on cybersecurity with the Norwegian Centre for Cybersecurity in Critical Sectors (NORCICS) – a Centre for Research-based Innovation (SFI).

Henning Taxt, Raymundo E. Torres-Olguin and Susanne Sandell at The National Smart Grid Laboratory. →

Photo: Daniel Albert/SINTEF

Conclusions

Organisation of research work and annual work plans

To fully leverage the advantages of a large Centre for Environment-friendly Energy Research (FME) – ensuring oversight, structuring research and pilot projects, and fostering long-term collaboration between research and industry in a broad field like the future power grid – an overarching structure with a shared vision and direction is vital.

Clear annual work plans, reviewed across all work packages (WPs) and firmly anchored within the consortium, as well as a long-defined long-term strategy, are also essential for success, as each WP is complex and could function as a standalone project.

A well-structured approach to reporting results, tracking progress, and addressing deviations from research plans is equally important.

Photo: Ingvild Aursland/SINTEF

The WP leaders at the end of the Centre period. Left to right: Magnus Korpås, Susanne Sandell, Gerd Kjølle, Oddbjørn Gjerde and Maren Istad.

Project management and management group

The Centre's project management has benefited from having the same director throughout its duration. The management structure included an extended management group, comprising WP leaders and coordinators from research partners without designated work package leaders. This group held regular meetings, typically every two weeks.

A smaller core team focused on administration, consisting of the Centre director, Centre coordinator, and scientific coordinator, with support from a project coordinator and a communications advisor at the host institution. This setup allowed research leaders to concentrate on long-term research objectives.

See also Chapter 5: *Basic facts about the Centre*.

Information and communication management

CINELDI had a well-defined communication strategy, managed by professional communication advisors, to structure and facilitate external outreach. In the early years, communication efforts primarily focused on internal coordination. However, as research results became available, the focus gradually shifted towards dissemination.

In recent years, the Centre transitioned from holding exclusively internal webinars for consortium members to making them publicly accessible and promoting them via LinkedIn. Similarly, the annual *CINELDI Days*, initially a closed two-day event for the consortium, was adapted to include an open invitation to the sector on the second day.

Centre building activities

CINELDI had a structured plan for user partner involvement and actively facilitated meaningful engagement arenas. Group work and discussions were frequently used, with ample time for informal interactions during breaks.

The Centre successfully organised biannual joint events, running from lunch to lunch, and included a dinner with a small social program. Partner feedback indicated that these events were valuable, not only for staying updated on the latest research results, but also as a networking platform for discussing potential collaborations, including ongoing and future spin-off projects.

Ensuring active participation from all partners

CINELDI experienced a learning curve in securing active participation from partners at different levels within their organisations, and a definitive best practice has yet to be established. The sector in which CINELDI operates has not traditionally collaborated in this manner, and in the final evaluation, user partners shared valuable insights on this process.

A key success factor has been the development of scenario descriptions in collaboration with the consortium. These scenarios have been highly valuable to user partners, both as a structured process and as a tool for guiding R&D efforts in the sector.

One of the main takeaways from the mid-term evaluation was that several partners lacked internal leadership dedicated to anchoring and prioritising innovation. In response, the project management and Executive board placed greater emphasis on engaging higher levels within partner organisations in the later years of the Centre. This approach was reflected in the development of CINELDI's Knowledge Base, as well as in the *Strategy and roadmap for transitioning to a flexible, intelligent power grid*.

Key feedback from partners includes:

- All partners found participation in CINELDI valuable and important,
- The most highlighted benefits were access to a strong industry network and proximity to research and researchers,
- Consortium meetings, participation in expert groups and pilot projects, and the document library in the internal workspace were particularly useful resources.

Appendix

CINELDI Costs & Funding

Accounting report
Project Characteristics and Costs
(All figures in 1000 NOK)

Item	SINTEF Energi - HOST	NTNU	SINTEF DIGITAL	Total Research partners	DSO+TSO	Memberorganisations and gouvernment	Technology partners	Total cost user partners	Total cost
WP0 Centre management, direct cost and common activities	42 336	2 046	1 296	45 678	8 583	304	2 348	11 235	56 913
WP1 Smart grid development and asset management	19 781	6 342	8 563	34 686	10 612	464	3 587	14 664	49 350
WP2 Smart grid operation	19 729	12 782	13 297	45 807	10 375	456	3 522	14 352	60 160
WP3 Flexibility and interaction DSO/TSO (2022-2024)	10 390	10152	974	21 516	8 134	288	2 225	10 646	32 162
WP Interaction DSO/TSO (2016-2021)	6 322	6 937	1 928	15 187	5 741	203	1 570	7 515	22 702
WP4 Microgrids (2016-2021)	5595	8 862	3 382	17 839	6 743	239	1 845	8 827	26 665
WP5 Flexible resources in the power system (2016-2021)	8 126	6 172	656	14 954	5 653	200	1 546	7 400	22 354
WP6 Smart grid scenarios and transition strategies	18 960	5 080	997	25 036	9 464	335	2 589	12 389	37 425
WP Pilot	6 261	85		6 346	15 450	547	4 226	20 223	26 569
Equipment					5 000		2 161	7 161	7 161
Inkind Research partners	27 219	13 932	10 005	51 157				0	51 157
Total budget	164 720	72 388	41 098	278 207	85 755,50	3 036,70	25 619,00	114 411	392 618

Appendix 1

Accounting report
Funding
(All figures in 1000 NOK)

Item	SINTEF Energi - HOST	NTNU	SINTEF DIGITAL	Total Research partners	DSO+TSO	Memberorganisations and gouvernment	Technology partners	Total funding user partners (inkind+cash)	RCN Grant	Total funding		
WP0 Centre management, direct cost and common activities					11 905	845	739	13 489	32 189	45 678		
WP1 Smart grid development and asset management					9 040	642	561	10 243	24 443	34 686		
WP2 Smart grid operation					11 939	847	741	13 527	32 280	45 807		
WP3 Flexibility and interaction DSO/TSO (2022-2024)					5 608	398	348	6 354	15 162	21 516		
WP Interaction DSO/TSO (2016-2021)					3 958	281	246	4 485	10 702	15 187		
WP4 Microgrids (2016-2021)					4 649	330	289	5 268	12 571	17 839		
WP5 Flexible resources in the power system (2016-2021)					3 897	277	242	4 416	10 538	14 954		
WP6 Smart grid scenarios and transition strategies					6 525	463	405	7 393	17 643	25 036		
WP Pilot					1 654	117	103	1 874	4 472	6 346		
Equipment					5 000		2 161	7 161		7 161		
Inkind Research partners	27 219	13 932	10 005	51 157						51 157		
Inkind industry partners					80 755	3 037	23 458	107 250		107 250	% research inkind*	% userpartner funding*
Total budget	27 219	13 932	10 005	51 157	139 930	7 237	27 133	174 300	160 000	392 618	**13 %**	**44 %**

List of Post-docs, Candidates for PhD and MSc degrees during the full period of the centre

Postdoctoral research scientists at NTNU with financial support from the Centre budget

Name	M/F	Nationality	Scientific area	Years/period in the centre	Scientific topic	Main contact
Ida Marie Henriksen	F	Norway	Cultural and social research	2020-2024	The role of intermediaries in demand response service	Tomas Moe Skjølsvold
Olga Usachova	F	Ukrain	Cultural and social research	2023-2025	Electricity grids as a site of transformative innovation	Tomas Moe Skjølsvold
Younes Zahraoui	M	Algeria	Cybernetics	2023-2025	Flexibility as a resource in distribution system development and its impact on the Security of Electricity Supply	Sebastien Gros
Michele Garau	M	Italy	Information Security and Communication Technology	2018-2020	Modelling of Interactions and Interdependencies in Complex Systems of Power Grid and ICT Systems	Bjarne Helvik
Mario Blazquez De Paz	M	Spain	Industrial Economics and Technology Management	2017-2020	Modelling transition strategies towards smart distribution grids	Asgeir Tomasgard

Post-doctoral research scientists at NTNU working on projects in the Centre with financial support from other sources

Name	M/F	Nationality	Source of funding	Years/period in the centre	Scientific area	Scientific topic
Chendan Li	F	China	NTNU - SO	2019-2021	Electric Power Engineering	Methods and tools for stability assessment of micro-grid systems dominated by Power Electronic converters.
Soumya Das	M	India	ROME-project - Indnor	2020-2022	Electric Power Engineering	Integrated methods and tools for planning and operation of Microgrids

Appendix 2

PhD candidates at NTNU who have completed with financial support from the Centre budget

Name	M/F	Nationality	Scientific area	Years/period in the centre	Thesis title	Main thesis Advisor
Stine Fleischer Myhre	F	Norway	Electric Power Engineering	2019-23	Reliability Assessment Tool for Modern Electrical Distribution Systems – A Monte Carlo Simulation Approach	Olav Bjarte Fosso
Ingvild Firman Fjellså	F	Norway	Interdisciplinary Studies of Culture	2017-22	Just Flexibility? The Envisioned Role of End Users in Future Electricity Systems	Tomas Moe Skjølsvold
Güray Kara	M	Turkey	Industrial Economics and Technology Management	2017-21	Stochastic programming in analyses of flexibility in power systems and markets	Asgeir Tomasgard
Mohammad Ali Abooshahab	M	Iran	Cybernetics	2017-21	Dynamic State Estimation for Electrical Power Grids	Morten Hovd
Kasper Emil Thorvaldsen	M	Norway	Electric Power Engineering	2018-22	A Long-term Strategy Framework for Flexible Energy Operation of Residential Buildings	Hossein Farahmand
Fredrik Göthner	M	Norway	Electric Power Engineering	2017-21	Stability and Power Quality Improvements to Facilitate Wide-Scale Deployment of Future Microgrids	Morten Hovd
Emil Dimanchev	M	Bulgaria	Electric Power Engineering	2020-24	Decarbonization of energy systems under risk	Magnus Korpås

PhD candidates at NTNU who have completed with other financial support, but associated with the Centre

Name	M/F	Nationality	Source of funding	Years in the centre	Scientific area	Thesis title	Main thesis Advisor
Sjur Føyen	M	Norway	NTNU - SO	2018-2022	Electric Power Engineering	Modelling of frequency-coupled power electronics systems: Automated model generation and chirp frequency scanning, applied to single-phase VSCs	Olav Bjarte Fosso
Per Aaslid	M	Norway	SINTEF - PhD	2018-2021	Electric Power Engineering	Optimal coordination of renewable sources and storage in energy-constrained power systems	Olav Bjarte Fosso
Mostafa Barani	M	Iran	NTNU - RSO-TSO Energi	2018-2021	Electric Power Engineering	Reliability Studies in Information and Communication Technologydominated Distribution Systems: Adequacy Assess-ment of Cyber-Physical Distribution Networks Including Microgrids	Vijay Vadlamudi
Matthias Hofmann	M	Germany	Statnett/NFR (Industry PhD)	2018-2021	Electric Power Engineering	Implicit demand side flexibility as an alternative to investments in the transmission grid	Karen Byskov Lindberg
Sigurd Bjarghov	M	Norway	NTNU DigEco project	2018-2022	Electric Power Engineering	Designing grid tariffs and local electricity markets for peak demand reduction in distribution grids	Hossein Farahmand

Name	M/F	Nationality	Source of funding	Years in the centre	Scientific area	Thesis title	Main thesis Advisor
Kjersti Berg	F	Norway	FINE KSP	2021-2023	Electric Power Engineering	Local energy communities: Member benefits and grid impact under various regulatory frameworks	Hossein Farahmand
Sverre Foslie	M	Norway	SINTEF - PhD	2021-24	Electric Power Engineering	The Role of Process Flexibility for Faster Decarbonization of Industrial Energy Demands	Magnus Korpås

PhD students at NTNU with financial support from the Centre budget who still are in the process of finishing studies

Name	M/F	Nationality	Scientific area	Years in the centre	Thesis topic	Main thesis Advisor
Fredrik Bakkevig Haugli	M	Norway	Information Security and Communication Technology	2017-2024	Distributed and centralized control to support smart grid operation with high quality in a cost-efficient way	Poul Heegaard
Kalpanie Mendis	F	Sri Lanka	Information Security and Communication Technology	2018-2024	5G for Low-Latency, Secure, and Dependable Communication Services for Fault Handling in Micro Grids	Poul Heegaard
Romina Muka	F	Albania	Information Security and Communication Technology	2018-2022	Self-Healing and Autonomous Smart Grid Operation	Poul Heegaard
Natasa Gajic	F	Serbia	Information Security and Communication Technology	2021-2024	Methods for assessment of the cyber-physical security of smart grid operations in the presence of large-scale and controllable DER	Stephen D Wolhusen
Outi Pitkänen	F	Finland	Interdisciplinary Studies of Culture	2020-2024	The loads that connect us: how Norwegian actors work to produce flexible electricity consumption	Tomas Moe Skjølsvold
Jarand Hole	M	Norway	Electric Power Engineering	2022-2026	Integrasjon av solkraft og system/-nettutfordringer	Magnus Korpås
Maciej Grebla	M	Poland	Electric Power Engineering	2019-2020	Power system protection in micro-grids	Hans Kristian Høidalen
Dung-Bai Yen	M	Taiwan	Industrial Economics and Technology Management	2021-2024	Trasition pathways for smart distribution grids in view of market designs, regulation and other incentives	Maria Lavrutich

Appendix 2

MSc candidates with thesis related to the Centre research agenda and an advisor from the Centre staff

All CINELDI master thesis are linked in full-text from cineldi.no

Name	Scientific area	Year(s) in the centre	Thesis title
Jørgen S. Erdal	Electric Power Engineering	2017	Stochastic Optimisation of Battery System Operation Strategy under different Utility Tariff Structures
Sigurd N. Bjarghov	Electric Power Engineering	2017	Utilizing EV Batteries as a Flexible Resource at End-user Level
Vegard Skonseng Bjerketvedt	Electric Power Engineering	2017	Analysis of the Role of Energy Storage in Power Markets with Strategic Players
Martin Berg-Leirvåg	Electric Power Engineering	2017	Opprettelse av stegvis aggregeringsheuristikk og aggregeringsmodeller for vannkraftsystemer.
Dimitri Quentin Alexis Pinel	Industrial Economics and Technology Management	2017	Hydrogen Production from Wind and Solar Power in Weak Grids in Norway
Anders Holvik	Electric Power Engineering	2018	Virtual Impedance Techniques for Power Sharing Control in AC Islanded Microgrids
Edem Avevor	Information Security and Communication Technology	2018	Security of the Smart Grid
Elise Tveita	Electric Power Engineering	2018	Methods for Cost Allocation Among Prosumers and Consumers Using Cooperative Game Theory
Erlend Grande	Engineering Cybernetics	2018	Data gathering and -assembling from several smart meter HAN ports
Fredrik Blom	Electric Power Engineering	2018	A Feasibility Study of Blockchain Technology As Local Energy Market Infrastructure
Henrik Willett	Information Security and Communication Technology	2018	Security evaluation of communication interfaces on smart meters
Håkon Edøy Hanssen	Engineering Cybernetics	2018	Data acquisition and analysis of acquired data from geographically distributed sensors connected by 2G / 4G technology
Ingrid Marie Andersen	Electric Power Engineering	2018	Stochastic Optimization of Zero Emission Buildings
Isa Agnete Halmøy Fredriksen	Information Security and Communication Technology	2018	Cyber Security in Smart Meters: Vulnerability Investigation in the Home Area Network Port
Jarand Hole	Electric Power Engineering	2018	Integrasjon av distribuert fornybar energi i Trøndelag
Kasper Thorvaldsen	Electric Power Engineering	2018	Multi-Market Optimization of Energy Storage Taking Into Account Uncertainty
Lene Marie Hope Rognan	Electric Power Engineering	2018	Photovoltaic Power Prediction and Control Strategies of the Local Storage Unit at Campus Evenstad
Mads-Emil Kvammen, Sjur Frøyen	Electric Power Engineering	2018	A signal analysis toolbox for power system identification in Smart Grids
Marit Tundal	Engineering Cybernetics	2018	Utilizing Blockchain Technology for Settlement in a Microgrid
Martin Lillebo	Electric Power Engineering	2018	Impact of EV Integration and Fast Chargers in a Norwegian LV Grid - An analysis based on data from a residential grid in Steinkjer

Name	Scientific area	Year(s) in the centre	Thesis title
Ruben Buchmann	Electric Power Engineering	2018	Harmonic Sharing in Microgrid Applications - Modeling, Developing and Evaluating a Microgrid Control System With Harmonic Sharing Capability
Signe Gjørven	Electric Power Engineering	2018	Integrasjon av sol i det norske kraftsystemet
Sondre Flinstad Harbo	Electric Power Engineering	2018	Tackling Variability in Renewable Energy Production and Electric Vehicle Consumption with Stochastic Optimization - The Benefits of Using the Stochastic Quasi-Gradient Method compared with Exact Methods and Machine Learning
Thea Ulrikke Øverli	Electric Power Engineering	2018	Forbrukerfleksibilitet som en ressurs i fremtidens kraftsystem
Andreas Rise Mathisen	Electric Power Engineering	2019	Continuous-Time Unit Commitment using spline interpolation
Bernt Johan Damslora	Engineering Cybernetics	2019	Data collection in a cellular sensor network with nRF9160
Fredrik Heistad, William A. Kristensen	Information Security and Communication Technology	2019	Prediksjon av feil i det norske strømnettet
Guro Sæther	Electric Power Engineering	2019	Peer-to-Peer Energy Trading in Combination with Local Flexibility Resources in a Norwegian Industrial Site
Hanne Høie Grøttum, Siri Førsund Bjerland	NTNU, Industrial Economics and Technology Management	2019	Modelling coordination schemes for the transmission and distribution system operators in the power system
Hege Bruvik Kvandal	Electric Power Engineering	2019	Toolbox for Specialized Power System Analysis
Håkon Eidsvik	Electric Power Engineering	2019	Dynamic simulation of power systems based on a second-order predictor-corrector scheme
Ingvild Skaftun	Engineering Cybernetics	2019	Effektforbruk ved svømmeanlegg (Pirbadet)
Jonas Riseth, Stine Fleischer Myhre	Electric Power Engineering	2019	Interaction Strategies for an Optimal Grid Integration of Microgrids
Kjersti L. Runestad	Electric Power Engineering	2019	Adaptive Protection of an Inverter- Dominated Microgrid and Testing at the Smart Grid Laboratory at NTNU
Line Nyegaard	Electric Power Engineering	2019	Multi-Period AC Optimal Power Flow for Distribution Systems with Energy Storage
Marius Lervik	Engineering Cybernetics	2019	System for acquisition and analyzing of data from smart meters
Marte Brurås	Electric Power Engineering	2019	Impact of fast charging stations on the reliability of electricity supply in distribution networks
Martine Johanne Nordengen Baksvær	Electric Power Engineering	2019	EMD and Online EMD for Harmonic Detection in Power Systems
Mathias Melby	Electric Power Engineering	2019	Comparison of virtual oscillator control and droop control in an inverter-based stand-alone microgrid
Mats Kornelius Karlsen	Engineering Cybernetics	2019	Energioptimalisering og mikrogrid, Granåsen skisenter

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Name	Scientific area	Year(s) in the centre	Thesis title
Nathalie Skyttermoen	Electric Power Engineering	2019	A method for planning a fast charging station
Oda Hjelme	Electric Power Engineering	2019	Optimal PV Inverter Active and Reactive Power Control in Distribution Grids With High Amounts of Solar PV
Ola Mathias Almenning	Electric Power Engineering	2019	Reducing Neighborhood Peak Load with a Peer-to-Peer Approach under Subscribed Capacity Tariffs
Rodrigo Villanueva Revenga	Electric Power Engineering	2019	A Shorterm assessment of flexibility analyzing different levels of VRES deployment in a Unit Commitment model
Steinar Halsne	Electric Power Engineering	2019	Stabilitetsvurdering ved Nettimpedansmetoden og Adaptiv Kontroll
Tonje Leine Lunden	Electric Power Engineering	2019	Analyse av forbruksmålinger fra smarte nettstasjoner for planlegging og drift av distribusjonsnett
Torbjørn Slinde	Electric Power Engineering	2019	Prosesstøtte og visualisering i neste generasjons asset management
Adrian Cruz	Electric Power Engineering	2020	Investment Analysis for Residential Storage and PV Systems under Spanish Grid Tariffs
Alexander Hansen Bakken, Bjørn O. Gjørven	Computer Science + Electric Power Engineering	2020	Design and Validation of a Novel Architecture for Virtual Smart Grid Cyber Ranges
Bendik Balstad Deraas	Communication Technology	2020	Modelling and Analysis of Interdependencies between Financial, Communication and Power System Infrastructures in a Smart Grid Scenario
Bjørnar Veie	Engineering Cybernetics	2020	Balancing Solar Energy and Load Consumption given Different Load Consumption Profiles
Christian Fredrik Marquez Træland	Electric Power Engineering	2020	Grid Tariffs for Fast Charging Stations in the Norwegian Distribution Grid
Doney Abraham	Information Security and Communication Technology	2020	Application of Machine Learning in IoT enabled Smart Grids for Attack Detection
Eirik Haugen	Electric Power Engineering	2020	Optimization of battery energy storage system: A case study for an electric vehicle fast-charging station
Eirik Haugen Lillefosse	Electric Power Engineering	2020	Towards DC-microgrids with Stability-Preserving Plug-and-Play Features: Passivity-Based Control Design of DC/DC Converters under Compensated Modulation
Eirik Ivarsøy	Electric Power Engineering	2020	Optimal planning of fast charging stations for EVs – A Norwegian case study
Erik Log Rogne	Electric Power Engineering	2020	Analysis and visualization of reinvestment scenarios for distribution networks
Erik-Anant Stedjan Narayan	Electric Power Engineering	2020	Dynamically Simulating Power Systems Using a Self-Adaptive Time Step Method
Erlend Westad	Electric Power Engineering	2020	Instantaneous Frequency Identification in Microgrids Through Adaptive Data Analysis

Name	Scientific area	Year(s) in the centre	Thesis title
Fabian Skarboe Rønningen	Electric Power Engineering	2020	Impedance-Based Stability Analysis and Adaptive Control of Grid-Connected Converter
Hannah Magnussen	Electric Power Engineering	2020	Price formation and market balancing in a local flexibility market using Model Predictive Control
Håvard Refvik	Information Security and Communication Technology	2020	Robustness of short-term load forecasting models for smart grids
Jon Hvideberg Holte	Electric Power Engineering	2020	An analysis of energy storage system with wind power for multi-market operation under uncertainty
Linnea Espevik	Electric Power Engineering	2020	Techno-economic optimization of energy storage for increased wind farm integration
Liv Ringheim	Electric Power Engineering	2020	Grid Impact from Increased Prosumer Penetration in the Norwegian Distribution Grid
Manuel Perez Bravo	Exchange – Erasmus Mundus	2020	Agent-based modelling of EV charging scheduling towards optimized operation in Smart Grids
Maren Refsnes Brubæk	Electric Power Engineering	2020	Battery Storage as Alternative to Grid Reinforcement in the Low-Voltage Network
Mari Myrvold Osnes	Electric Power Engineering	2020	Analyse av lastendringer på nettstasjonsnivå som følge av solkraftproduksjon på privathus og næringsbygg
Markus Formo	Electric Power Engineering	2020	Continuation Power Flow as a tool for multi-step simulation in meshed and radial power systems
Marthe Fogstad Dynge	Electric Power Engineering	2020	Impact of Local Electricity Markets and Peer-to-Peer Trading on Grid Operations in a Norwegian Low-Voltage Distribution Grid
Matias Lunde Ellingsen	Electric Power Engineering	2020	Security-Constrained Optimal Power Flow in Meshed Distribution Grids
Mohamed Farooq	Electric Power Engineering	2020	TSO - DSO Coordination for Voltage Control: Simulaiton Study and Use Case Development
Olav Henrik Skonnord	Electric Power Engineering	2020	The Influence of Local Energy Tariffs on a Norwegian Local Market
Ole Bendik Midtbust	UiO - Department of Informatics	2020	Approach to software testing in the context of smart power grids
Racin Gudmestad	UiS - Communication technology	2020	Delayed Integrity Check for IEC 61850 Communication
Rune Steig	Electric Power Engineering	2020	Towards Energy Synchronization of Two-Level Voltage Source Converters
Sarminal Gunabala; Sara Eriksen	Information Security and Communication Technology	2020	Nettselskapers involvering av underleverandører i hendelseshåndtering ved cyberangrep
Tormod Habbestad Aarnes	Electric Power Engineering	2020	High-Power Electric Charging in the Norwegian Distribution Grid
Øystein Molvik	Engineering Cybernetics	2020	Network of sensors for measurement of potential for delivery of electrical energy from solar panels

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Name	Scientific area	Year(s) in the centre	Thesis title
Åsmund Sælen	Electric Power Engineering	2020	Topflow, a Toolbox for Specialized Power System Analysis
Amanda Njøten, Stine Morberg Larsen	Electric Power Engineering	2021	Optimal Resource Allocation and Pricing for Distributed Demand-Side Flexibility Services
Anders Grøttås, Annvor Teigen Nestås	Electric Power Engineering	2021	Flexibility Solutions in Distribution Networks. Case Study Utsira
DanElectric Power Engineering Bolstad	Electric Power Engineering	2021	Interpretation of Electrical Load Forecasts using Explainable Artificial Intelligence
Erik Seeger Bjørnerem	Electric Power Engineering	2021	Analyzing optimal sizing and operation of renewable hydrogen systems
Erlend Øye	Electric Power Engineering	2021	A Practical Application of an Active Distribution Grid Planning Framework in Relation to a Pilot Area for New Energy Solutions
Frida Bratlie	Electric Power Engineering	2021	Leveraging residential battery energy storage systems for voltage support in remote distribution grids with high penetration of renewables
Henrik Waterloo	Electric Power Engineering	2021	Predicting Domestic Hot Water Consumption in Buildings in Norway Using Machine Learning
Ida Langseth	Electric Power Engineering	2021	Voltage Support with Reactive Power from Fast Charging Stations with Local Energy Storage and Production
Ine Ingebrigtsen Svendsen	Electric Power Engineering	2021	Modelling Electrical Flexibility from Domestic Water Heaters
Jacob Wang	Electric Power Engineering	2021	Long-term Peak Power and Energy Forecasting in Norwegian Electricity Grids
Jostein Johansen Lyngen	Engineering Cybernetics	2021	Optimal dimensjonering og drift av mikronett
Kyrre Kirkbakk Fjær	Electric Power Engineering	2021	Analysis of Dynamic Pricing to utilise Spatial Flexibility in Heavy-Duty Electric Vehicle Charging Demand
Lars Halvdan Flå	Engineering Cybernetics	2021	Threat Modeling Framework for Smart Grids
Malin Kaaløy	Electric Power Engineering	2021	Assessing local flexibility resources in a Zero Emission Neighbourhood with focus on space heat demand and battery storage
Mari Langås, Sanna Løfqvist	Information Security and Communication Technology	2021	Cyber security Preparedness Exercises in Smart Grid: Collaboration with Suppliers During Incident Response
Maria Claire Westad	Electric Power Engineering	2021	A Stochastic Simulation Tool for Generating Hourly Load Profiles for Residential EV Charging, Based on Real-World Charging Reports
Matias Kraft Vistnes	Electric Power Engineering	2021	Analysis of Interdependence in Electrical Distribution Power Systems and corresponding Information and Communications Technology Systems using Monte Carlo Simulations
Oda Skeie	Electric Power Engineering	2021	A Control Strategy for Seamless Interconnection of Microgrids in a Multigrid Configuration
Ole Andreas Sloth	Electric Power Engineering	2021	Demand response verification using baseline estimation and load disaggregation

Name	Scientific area	Year(s) in the centre	Thesis title
Synnøve Hovden	Electric Power Engineering	2021	An Optimal Model Predictive Control-Based Energy Management System for Microgrids
Viljar Stensaker Stave	Electric Power Engineering	2021	Optimal Utilisation of Grid Capacity for Connection of New Renewable Power Plants in Norway
Andreas Sandvik Høimyr	Electric Power Engineering	2021	An analysis of electric vehicle user-behaviour at a smart charging station
Alvar Øyasæter	Electric Power Engineering	2022	Transition Strategies for Smart Grid: Evaluating future scenarios on a distribution grid
Andreas Aadnøy	Electric Power Engineering	2022	A Case Study on the Grid Integration of Electric Vehicles and Solar Power using the CINELDI test grid
Anne Marthe Ter Woerds Christensen	Electric Power Engineering	2022	Application of Stochastic Dual Dynamic Programming to evaluate long-term price signals in short-term optimisation of energy use in buildings
Eivind Jamessen	Electric Power Engineering	2022	Economical Optimisation of Wind Powered Pump Hydro Storage Systems in Norway
Håkon Teppan	UiS - Communication technology	2022	Utilize GitOps for Smart Grid Security Lab
Ine Vågane	Electric Power Engineering	2022	Local flexibility Market - TSO and DSO coordination
Ingrid Maria Sundfør	Electric Power Engineering	2022	Flexibility in Distribution Systems through PyDSAL
Jon Roaldsøy Walderhaug	Electric Power Engineering	2022	Flexibility markets as a tool to solve grid problems
Mikal-Andre Tvedt	Electric Power Engineering	2022	Optimal Operation of Flexible Assets in a Residential Energy System: A Rolling Horizon Approach
Robert Grindborg Karlsen	Electric Power Engineering	2022	Evaluation of available capacity in distribution grids
Runar Hillestad	Electric Power Engineering	2022	A co-simulation framework to coordinate battery optimization and load flow - Improving voltage quality in the distribution grid
Tom Erik Øyen	Electric Power Engineering	2022	EV Fast Charging Station Potential for Defence Service Provision
Simran J. K. Sandhu, Marthe Vågen	Electric Power Engineering	2022	Baseline Estimation for Flexibility Validation
Anders Ryssdal	Electric Power Engineering	2022	Designing a Zonal Flexibility Market and Modelling Strategic Behaviour in Combination with the Intraday Market: Combining Optimization and Machine Learning Approaches
Victor Aasvæer	Electric Power Engineering	2022	Designing a Zonal Flexibility Market and Modelling Strategic Behaviour in Combination with the Intraday Market: Combining Optimization and Machine Learning Approaches
William Solberg	Industrial Economics and Technology Management	2022	The utilization of power purchase agreements, granular guarantees of origin, and shared batteries to increase the value of prosumer solar surplus
Ine Solsvik Vågane	Industrial Economics and Technology Management	2022	Local Flexibility Market - TSO and DSO coordination

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Name	Scientific area	Year(s) in the centre	Thesis title
Anna Liv Leikanger Aasen	Electric Power Engineering	2023	Integration of Fast-Charging Station in the Distribution System - Exploring the Potential of Alternative Grid Connection Agreements
Clemens Martin Muller	Electric Power Engineering	2023	Physics informed neural networks in radial load flow calculations
Erlend Vabø	Electric Power Engineering	2023	Electric water heaters as flexible energy resources in the power grid
Erlend Waage	Electric Power Engineering	2023	Distribution grid planning with flexible measures
Ferdinand Lindal	Electric Power Engineering	2023	Impact of Industrial Size Battery Storage Systems on Electricity Price Distribution
Ingrid Rodahl Kvale	Electric Power Engineering	2023	Prediction of power, energy and hydrogen demand in a zero-emission port
Ingvild Eline Olsen	Electric Power Engineering	2023	Multimarket Services for Stationary Batteries - Considering Activation of Frequency Containment Normal Operation Reserves
Jon Olav Båtbukt	Electric Power Engineering	2023	Quantification of the value of flexible demand and renewable energy resources in a local energy market
Karl Fredrik Anker Wirgenes	Electric Power Engineering	2023	Proposal and Evaluation of a New Short Circuit Protection Algorithm for Active Meshed Distribution Grids
Lars Skjelbred Nygaard	Electric Power Engineering	2023	Investments in Low-Carbon Power Generation and Energy Storage under Uncertainty
Magnus Rein Hatletveit	Electric Power Engineering	2023	A Case Study on the Impact of Vehicle-to-Grid on Reliability of Supply in a Norwegian Distribution System
Marius Rasmussen	Electric Power Engineering	2023	Potential of Hydrogen Technology for Coastal Electrification: Minimizing Distribution Grid Impacts through Flexibility
Sofie Lorentzen	Electric Power Engineering	2023	Potential of Hydrogen Technology for Coastal Electrification: Minimizing Distribution Grid Impacts through Flexibility
Denise Lusuegro Burgos	Information Security and Communication Technology	2024	DoS Threat to Smart Grids: Review, analysis, and challenges
Egil Espnes	Electric Power Engineering	2024	Integrating Electric Vehicles into the Norwegian Power Grid: A Case Study
Jorge Ivan Jaramillo Hoyos	Information Security and Communication Technology	2024	Implementing Smart Grid Use-case on Top of 5G
Lill Mari Engan	NMBU REALTEK	2024	Load Shifting Potential of Local Energy Communities with Seasonal Thermal Energy Storage
Jonas Henrik Pinderud	Electric Power Engineering	2024	Operation of an EV parking lot subject to capacity-based grid tariffs offering grid services through demand response
Andreas Fosse Hansen	Electric Power Engineering	2024	Operation of an EV parking lot subject to capacity-based grid tariffs offering grid services through demand response
Jacob Fredrik von Krogh	Electric Power Engineering	2024	Unlocking the Potential of Value Stacking in Norwegian distributions systems

Name	Scientific area	Year(s) in the centre	Thesis title
Espen Aglen	Electric Power Engineering	2024	Investigating the cost-effectiveness of flexible resources in a distribution grid to mitigate voltage problems
Astrid Elise Valle	Electric Power Engineering	2024	Multimarket Services for an Electic Vehicle - Considering Activation of Frequency Containment Normal Operation Reserves
Markus Andersen	Electric Power Engineering	2024	Model Predictive Control of a Home Energy Management System with a Rolling Horizon Strategy
Markus Karlsen Tørnkvist	Electric Power Engineering	2024	Bidding strategy for the local electricity market participants
Ola Furuhaug	Electric Power Engineering	2024	Intelligent elektrisk distribusjon – elbilladere som fleksibilitetsressurs i distribusjonsnett
Sivasuthan Raja	Electric Power Engineering	2024	Informatics-based approaches for estimating flexibility potential of electric water heaters
Sondre Modalsli Aaberg	Electric Power Engineering	2024	Security of Supply Framework for Distribution Systems

Appendix 3

CINELDI publications 2016-2024

Peer reviewed Papers – 2016

- Zaferanlouei, Salman; Ranaweera, Iromi; Korpås, Magnus; Farahmand, Hossein. Optimal Scheduling of Plug-in Electric Vehicles in Distribution Systems Including PV, Wind and Hydropower Generation, Energynautics GmbH 2016. ISBN 978-3-9816549-3-6. s. 462-467.

Peer-reviewed Journal publications – 2017

- Zecchino, Antonio; Marinelli, Mattia; Træholt, Chresten; Korpås, Magnus. Guidelines for Distribution System Operators on Reactive Power Provision by Electric Vehicles in Low Voltage Grids. Proceedings of CIRED, 2017.

Peer reviewed Papers – 2017

- Zaferanlouei, Salman; Korpås, Magnus; Farahmand, Hossein; Vadlamudi, Vijay Venu. Integration of PEV and PV in Norway Using Multi-Period ACOPF - Case study. IEEE Press 2017 ISBN 978-1-5090-4238-8.

Peer-reviewed Journal publications – 2018

- Bobinaite, Viktorija; Obushevs, Artjoms; Oleinkova, Irina; Morch, Andrei Z. Economically Efficient Design of Market for System Services under the Web-of-Cells Architecture. Energies 2018 ;Volum 11.(4) ENERGISINT.
- Černivec, Aleš; Erdogan, Gencer; Gonzalez, Alejandra; Refsdal, Atle; Romero, Antonio Alvarez. Employing Graphical Risk Models to Facilitate Cyber-Risk Monitoring - the WISER Approach. Lecture Notes in Computer Science 2018 ;Volum 10744. s. 127-146*.
- Lüth, Alexandra Rebecca; Zepter, Jan Martin Wilhelm; Crespo del Granado, Pedro; Egging, Ruud. Local electricity market designs for peer-to-peer trading: The role of battery flexibility. Applied Energy 2018 ;Volum 229. s. 1233-1243 NTNU.
- Oostenbrink, Jorik; Kuipers, Fernando; Heegaard, Poul Einar; Helvik, Bjarne Emil. Evaluating Local Disaster Recovery Strategies. Performance Evaluation Review 2018 ;Volum 46.(2) s. – NTNU.
- Sasan, Pirouzi; Aghaei, Jamshid; Niknam, Taher; Farahmand, Hossein; Korpås, Magnus. Exploring prospective benefits of electric vehicles for optimal energy conditioning in distribution networks. Energy 2018 ;Volum 157. s. 679-689 NTNU.
- Skjølsvold, Tomas Moe; Throndsen, William; Ryghaug, Marianne; Fjellså, Ingvild Firman; Koksvik, Gitte. Orchestrating households as collectives of participation in the distributed energy transition: New empirical and conceptual insights. Energy Research & Social Science 2018 ;Volum 46. s. 252-261 NTNU.

Peer reviewed Papers – 2018

- Bjarghov, Sigurd; Korpås, Magnus; Zaferanlouei, Salman. Value Comparison of EV and House Batteries at End-user Level under Different Grid Tariffs. I: 2018 IEEE International Energy Conference - ENERGYCON 2018, Limassol, Cyprus, 3-7 June, 2018. IEEE conference proceedings 2018 ISBN 978-1-5386-3669-5. s. – NTNU.
- Blom, Fredrik; Farahmand, Hossein. On the Scalability of Blockchain-Supported Local Energy Markets. I: 2018 International Conference on Smart Energy Systems and Technologies - SEST. IEEE conference proceedings 2018 ISBN 978-1-5386-5326-5. s. – NTNU.
- Degefa, Merkebu Zenebe; Sæle, Hanne; Petersen, Idar; Ahcin, Peter. Data-driven Household Load Flexibility Modelling: Shiftable Atomic Load. I: 2018 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT-Europe). IEEE Press 2018 ISBN 978-1-5386-4505-5. ENERGISINT.
- Esposito, Christian; Gouglidis, Antonios; Hutchison, David; Gurtov, Andrei; Helvik, Bjarne Emil; Heegaard, Poul Einar; Rizzo, Gianluca; Rak, Jacek. On the Disaster Resiliency within the Context of 5G Networks: The RECODIS Experience. I: 2018 European Conference on Networks and Communications (EuCNC). IEEE Press 2018 ISBN 978-1-5386-1478-5. s. – NTNU.
- Fosso, Olav B; Molinas Cabrera, Maria Marta. EMD Mode Mixing Separation of Signals with Close Spectral Proximity in Smart Grids. I: EMD Mode Mixing Separation of Signals with Close Spectral Proximity in Smart Grids. IEEE conference proceedings 2018 ISBN 978-1-5386-4506-2. NTNU.
- Føyen, Sjur; Kvammen, Mads-Emil B.; Fosso, Olav B. Prony's method as a tool for power system identification in Smart Grids. I: 24th IEEE International Symposium on Power Electronics, Electrical Drives, Automation and Motion, SPEEDAM 2018. IEEE conference proceedings 2018 ISBN 978-1-5386-4942-8. NTNU.
- Göthner, Fredrik T. B. W.; Midtgård, Ole-Morten; Torres Olguin, Raymundo E.; D'Arco, Salvatore. Effect of Including Transient Virtual Impedance in Droop-Controlled Microgrids. I: 2018

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- Harbo, Sondre; Zaferanlouei, Salman; Korpås, Magnus. Agent Based Modelling and Simulation of Plug-In Electric Vehicles Adoption in Norway. I: 2018 Power Systems Computation Conference PSCC. IEEE conference proceedings 2018 ISBN 978-1-910963-09-8. s. 1-7 NTNU.
- Sæle, Hanne; Morch, Andrei Z; Rikos, Evangelos J.; Canevese Silva Maria, Silva M.; Kosmecki, Michal. Utilization of distributed energy resources' flexibility in power system operation – Evaluation of today's status and description of a future concept. I: 2018 53rd International Universities Power Engineering Conference (UPEC). IEEE conference proceedings 2018 ISBN 978-1-5386-2910-9. ENERGISINT.
- Sæle, Hanne; Petersen, Idar. Electric vehicles in Norway and the potential for demand response. I: 2018 53rd International Universities Power Engineering Conference (UPEC). IEEE conference proceedings 2018 ISBN 978-1-5386-2910-9. ENERGISINT.
- Tveita, Elise; Löschenbrand, Markus; Bjarghov, Sigurd; Farahmand, Hossein. Comparison of Cost Allocation Strategies among Prosumers and Consumers in a Cooperative Game. I: 2018 International Conference on Smart Energy Systems and Technologies - SEST. IEEE conference proceedings 2018 ISBN 978-1-5386-5326-5. s. – NTNU.
- Zaferanlouei, Salman; Korpås, Magnus; Aghaei, Jamshid; Farahmand, Hossein; Hashemipour, Naser. Computational Efficiency Assessment of Multi-Period AC Optimal Power Flow including Energy Storage Systems. I: 2018 International Conference on Smart Energy Systems and Technologies - SEST. IEEE conference proceedings 2018 ISBN 978-1-5386-5326-5. s. 1-6 NTNU.

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- Adrah, Charles Mawutor; Yellajosula, Jaya R. A. K.; Kure, Øivind; Palma, David; Heegaard, Poul Einar. An IP Multicast Framework for Routable Sample Value Communication in Transmission Grids. Journal of Communications 2019 ;Volume 14.(9) p. 765-772 NTNU.
- Berglund, Frida; Zaferanlouei, Salman; Korpås, Magnus; Uhlen, Kjetil. Optimal Operation of Battery Storage for a Subscribed Capacity-Based Power Tariff Prosumer—A Norwegian Case Study. Energies 2019 ;Volume 12.(23) p. – NTNU.
- Bernsmed, Karin; Jaatun, Martin Gilje; Frøystad, Christian. Is a Smarter Grid Also Riskier? Lecture Notes in Computer Science (LNCS) 2019 ;Volume 11738. p. 36-52. SINTEF.
- Bitmead, Robert R.; Hovd, Morten; Abooshahab, Mohammad Ali. A Kalman-filtering derivation of simultaneous input and state estimation. Automatica 2019 ;Volume 108. p. – NTNU.
- Foros, Jørn; Istad, Maren Kristine; Morch, Andrei Z; Mathisen, Bjørn Magnus. Use case applying machine-learning techniques for improving operation of the distribution network. CIRED Conference Proceedings 2019. ENERGISINT SINTEF.
- Gil Gonzales, Walter Julian; Garces, Alejandro; Fosso, Olav B.; Escobar, Andres. Passivity-Based Control of Power Systems Considering Hydro-Turbine with Surge Tank. IEEE Transactions on Power Systems.
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- Hofmann, Matthias; Lindberg, Karen Byskov. Price elasticity of electricity demand in metropolitan areas – Case of Oslo. International Conference on the European Energy Market 2019 ;Volume 2019-September. NTNU SINTEF.
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- Sperstad, Iver Bakken; Korpås, Magnus. Energy Storage Scheduling in Distribution Systems Considering Wind and Photovoltaic Generation Uncertainties. Energies 2019 ;Volume 12.(7) ENERGISINT NTNU.
- Villanueava Revenga, Rodrigo; Crespo del Granado, Pedro; Oleinikova, Irina; Farahmand, Hossein. A Minute-To-Minute Unit Commitment Model to Analyze Generators Performance. International Conference on the European Energy Market 2019 ;Volume 2019-September. NTNU.
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- Almenning, Ola Mathias; Bjarghov, Sigurd; Farahmand, Hossein. Reducing Neighborhood Peak Loads with implicit Peerto-Peer energy trading under Subscribed Capacity tariffs. I: 2019 International Conference on Smart Energy Systems and Technologies - SEST. IEEE 2019 ISBN 978-1- 7281-1156-8. NTNU.
- Borgaonkar, Ravishankar Bhaskarrao; Jaatun, Martin Gilje. 5G as an Enabler for Secure IoT in the Smart Grid : Invited Paper. I: 2019 First International Conference on Societal Automation. IEEE 2019 ISBN 978-1-7281-3345-4. SINTEF.
- Degefa, Merkebu Zenebe; Sæle, Hanne; Andresen, Christian Andre. Analysis of Future Loading Scenarios in a Norwegian LV Network. I: 2019 International Conference on Smart Energy Systems and Technologies - SEST. IEEE 2019 ISBN 978-1- 7281-1156-8. ENERGISINT.
- Førland, Mathias Kjølleberg; Kralevska, Katina; Garau, Michele; Gligoroski, Danilo. Preventing DDoS with SDN in 5G. IEEE GLOBECOM Workshop on 5G wireless security, 2019.
- Førland, Mathias Kjølleberg; Kralevska, Katina; Garau, Michele; Gligoroski, Danilo. Towards 5G Intrusion Detection Scenarios with OMNeT++, OMNeT++ Community Summit, 2019.
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- Føyen, Sjur; Zhang, Chen; Fosso, Olav B.; Suul, Jon Are; Isobe, Takanori. Single-phase synchronisation with Hilbert transformers: a linear and frequency independent orthogonal system generator. IEEE COMPEL 2020.
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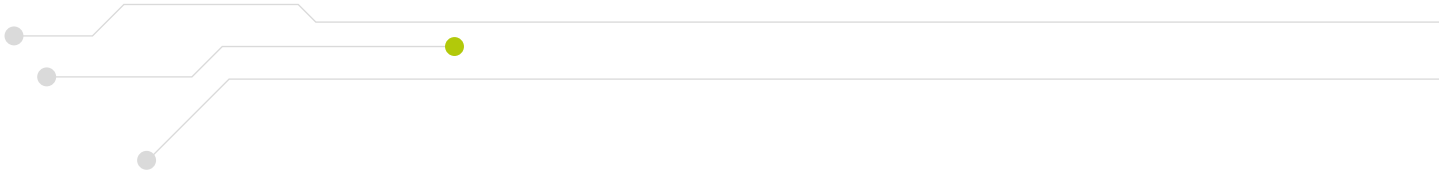

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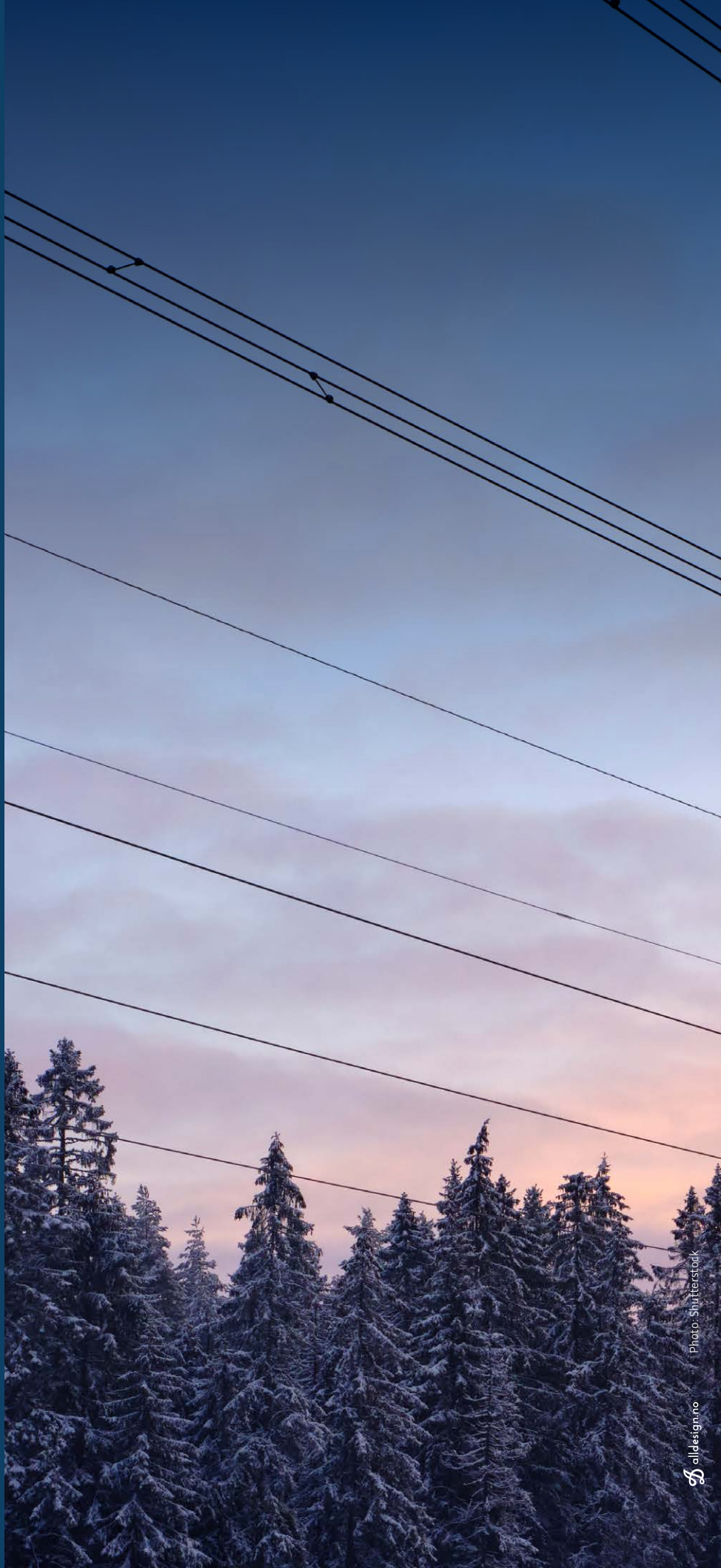

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