ANNUAL REPORT 2018

CINELDI

Centre for intelligent electricity distribution

CINELDI

- CINELDI develops the electricity grid of the future.
- CINELDI will work towards digitalising and modernising the electricity distribution grid for higher efficiency, flexibility and resilience.
- CINELDI will enable a cost-efficient realisation of the future flexible and robust electricity distribution grid.

Selected highlights from 2018

JUNE

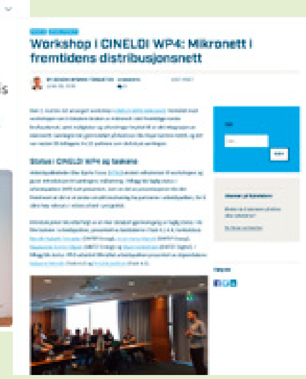
Workshop WP1, WP2, WP3 and WP5

MARCH

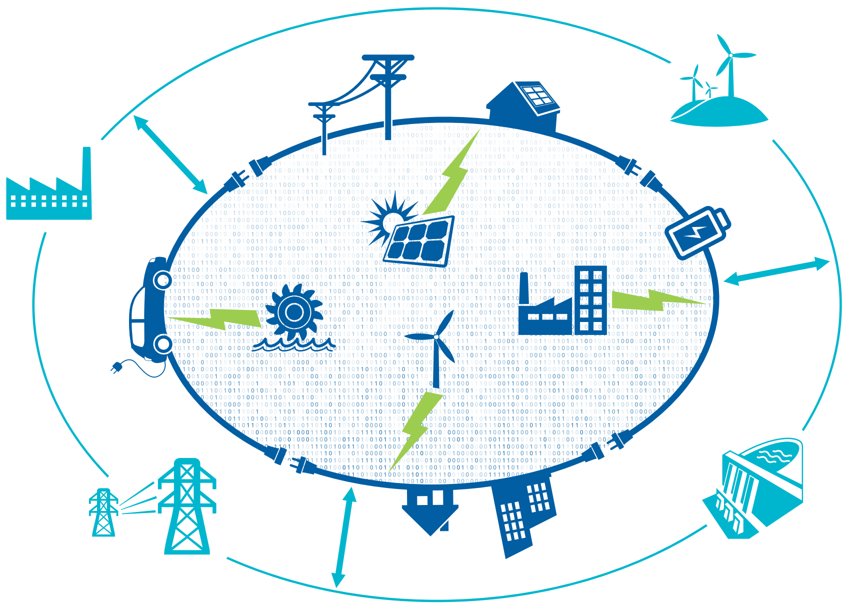
Partners visiting our SmartGrid Lab.

MAY

Workshop in WP4 and WP6



@CINELDI_FME



Selected highlights from 2018 - find more videos and stories on www.cineldi.no/Annual report 2018

OCTOBER

CINELDI days

Hafslund, winner of the CINELDI Prize

DECEMBER

Stories from CINELDI days

SEPTEMBER

CINELDI Op-ed in the national newspaper Dagens Næringsliv

Anne Steenstrup-Duch presenting CINELDI communication at the SmartGrid conference

NOVEMBER

Innovation Task Force

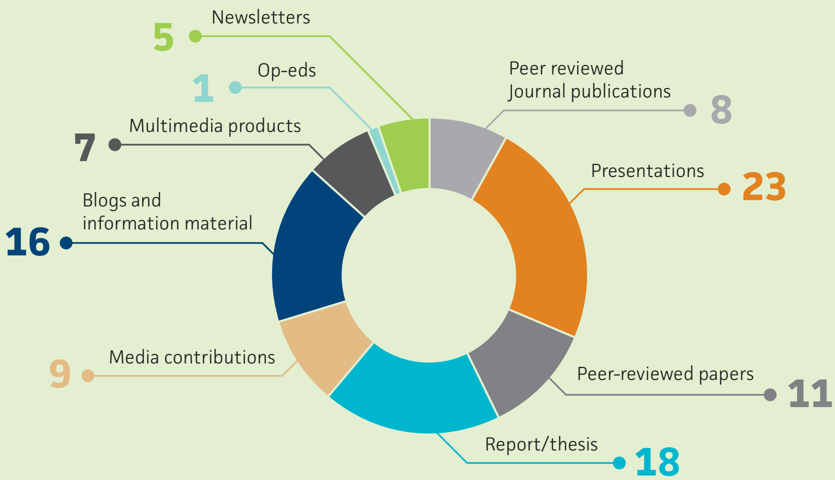
30 PARTNERS

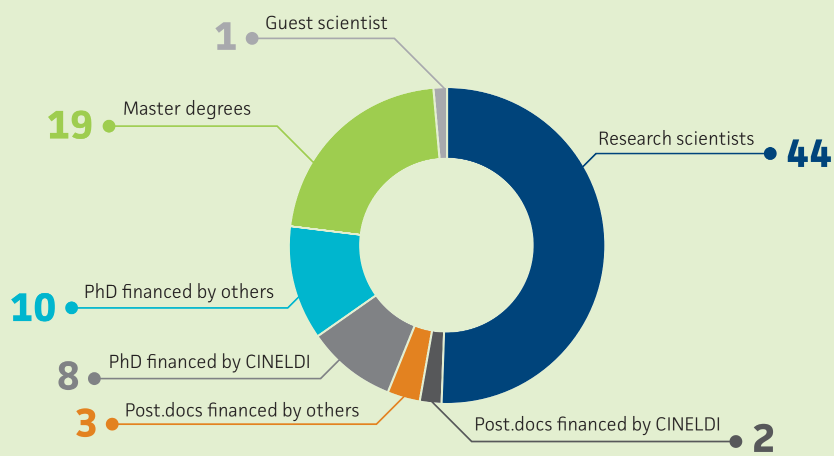
8 YEARS

365,1 MNOK

143 USER PARTNER PARTICIPANTS

2018 BY THE NUMBERS





Contents

MESSAGE FROM THE DIRECTOR

GERD KJØLLE IS THE CENTRE DIRECTOR OF CINELDI

Dr. Kjølle is Chief Scientist at the Energy Systems Department, SINTEF Energy Research. She is also Professor at NTNU, Department of Electric Power Engineering.

Gerd Kjølle holds a PhD in Electric Power Engineering from NTNU in 1996. She has more than 30 years of R&D experience from the electric power sector. Kjølle has collaborated with grid companies, electric power industry, Nordic and European transmission system operators and authorities, including multi-disciplinary projects and EU-projects. Her main fields of expertise are power system reliability and security of electricity supply. Achievements have resulted in solutions in use by grid operators and energy regulators, foundations for handbooks, decision support tools, guidelines of good practice, standards as well as regulations of grid companies. She has also contributed to education and recruitment of PhD and Master candidates to the electric power sector. Her international experience includes IEEE and CIRED, CIGRE as the Norwegian member of the study committee Active distribution systems and Distributed resources, and the EERA JP on Smart Grids.

The 2018 annual report for CINELDI is here, and with it comes some great results. Thanks to all partners for the contributions in CINELDI in 2018!

Our work towards building the smart energy system of the future is going strong, with excellent support from and cooperation with our 29 partners.

We've already taken the first steps towards establishing a planning methodology for the future distribution grid, taking into account new technologies on the customer side, and the massive amount of data made available from new sensors in the grid and the introduction of Internet of Things (IoT).

More than 100 mini scenarios for the future electricity distribution system innovation have been developed, in a foresight process through close cooperation with the consortium. The mini scenarios will be further elaborated within each work package forming the basis for future research. Some of the DSOs have already taken results from the foresight process in use in their strategic processes.

According to a survey among the Distribution System Operators (DSOs), they expect that in the future, a wider variety of flexible resources such as distributed generation, energy storage and electrical loads, will be used to enable a cost-efficient operation of the grid.

We have also studied the flexibility potential on the customer side, where every second household will reduce their electricity consumption if this can help others to get electricity back after an outage.

These are some of many exciting developments we've had throughout last year, and we hope you'll be just as pleased as we are reading the 2018 annual report.

Good reading!

GREETINGS FROM THE
CHAIRMAN OF THE BOARD

SIGURD KVISTAD IS CURRENTLY HEAD OF DIVISION OPERATIONAL CONTROL AT HAFSLUND NETT
Sigurd Kvistad has more than 30 years of experience from the electricity grid sector where he has been responsible for contractor operations, development projects, grid planning and grid operation.

Apart from being Chair of the board in CINELDI, he is also Chair of the board in the Norwegian Smart Grid Centre. Kvistad has taken part in many R&D projects within Smart Grids, as the project owner of several ongoing projects at Hafslund Nett, and he is a member of the R&D committee in the company.

Kvistad also takes part in different fora in the electricity grid sector related to the future grid as well as regulation of the grid companies.

Thanks to all in CINELDI for a well done first real working-year in the research centre.

All work packages and research tasks are well under way and the first results have been disseminated in different fora as well as at international conferences and published in international journals. This comprises self-healing in distribution grids, machine learning for fault localisation, opportunities and challenges with microgrids in Norway, electrical vehicles in Norway and potentials for demand response. In addition, 109 mini scenarios have been developed, for use in the research in the other work packages. This work is performed in close cooperation between research partners and user partners.

Through pilot projects in the Smart Grid Laboratory and in living labs at user partners, CINELDI aims to test and verify ideas and concepts in close cooperation between researchers and the industry. A new protection concept is tested in the lab giving promising results, and further testing will now continue in the real grid.

The Scientific Committee (SC) is a good arena for international cooperation, and SC has provided useful inputs to the work. The first PhD candidates have started their research and many master projects are performed.

Although CINELDI is well under way, we have also met some challenges in 2018. Recruiting PhD candidates has shown to be more challenging than expected. It has also taken more time than expected to develop and get the pilot projects up and running.

The CINELDI Board cooperates very well with the centre management and there is work going on revising the CINELDI strategy. Based on the experiences from 2018, dissemination of results will be emphasised in 2019.

INTRODUCTION

Today's distribution grid is ageing and was not designed for integration of vast amounts of intermittent electricity generated by solar and wind sources and the increasing electrification, e.g. of the transport sector. The smart distribution grid of the future, Smart Grid, will help to realise the flexibility resources inherent in electricity consumption, production and storage. The use of new sensors and smart components and communication makes it possible to monitor and operate the electricity grid in new ways - to improve usage of the existing grid and reduce the need for investments.

The future electricity system is characterised by a significant increase in complexity compared to today's situation, especially at the distribution level. Integration of distributed generation, electrical transport, electrical storage, flexible customers and new ICT solutions, results in new interactions and dynamics in the system of systems that comprises the Smart Grid. This demands a new and holistic approach to the grid operation and development while ensuring the security of electricity supply. The sustainability targets for the future cannot be met unless the necessary transformation of the electricity distribution system is addressed.

In 2016, FME CINELDI was established as one of eight new Centres for Environment-friendly Energy Research. The Centre will provide new visionary smart grid-solutions and test them in laboratory and real-life environments. This will pave the ground for increased distribution from renewable resources, electrification of transport, and more efficient power and energy use both in private homes and in industry. CINELDIs challenge is to develop a knowledge-base, new technologies and solutions enabling the transformation towards a flexible, intelligent and robust distribution grid[1] and in a socio-economically efficient way meeting future grid requirements.

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

VISION, MISSION AND GOALS

CINELDI VISION

CINELDI develops the electricity grid of the future.

CINELDI MISSION

CINELDI will work towards digitalising and modernising the electricity distribution grid for higher efficiency, flexibility and resilience.

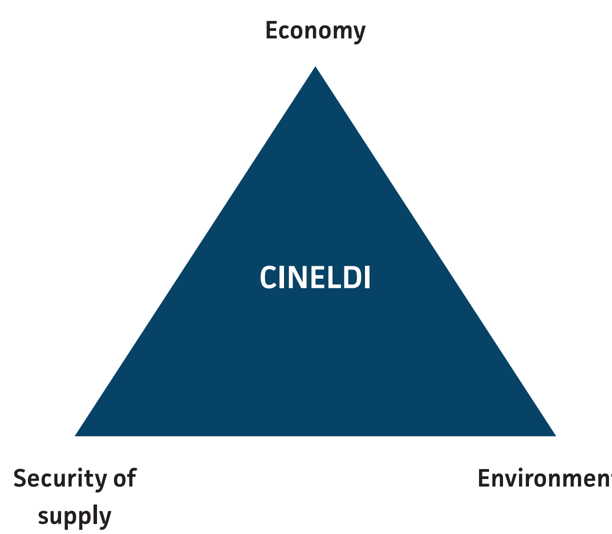
By acting as a national hub for long-term research and innovation within intelligent electricity distribution, CINELDI will bring together many innovative stakeholders for the development and implementation of new technologies, work processes and solutions to develop the electricity grid of the future.

CINELDI is equipped to tackle the challenge with its unique combination of academic resources, computer modelling and simulation facilities, the Norwegian Smart Grid Laboratory infrastructure[2], and pilots and demos integrating the involvement from industry partners.

GOALS

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

One of the main goals of transforming today's ageing and passive electricity grid into a flexible, intelligent and robust grid for the future, is to lay the foundation for reaching the energy and climate goals related to increasing distributed generation from renewable energy sources, electrification of transport and efficient energy use. This transformation should be made with acceptable costs, without jeopardising the security of electricity supply which is increasingly important in an even more electrified world.



Energy trilemma[3]

2 https://www.sintef.no/en/all-laboratories/smartgridlaboratory/

3 A trilemma might be interpreted as a choice between three unfavourable options, a trade-off between three goals, in which two are pursued at the expense of the third. The objective might be to achieve all three goals within the preferences and interests of the stakeholders in question. (see e.g. https://www.carbonbrief.org/climate-rhetoric-whats-an-energy-trilemma)

Providing electricity with a high security of supply, which is also affordable, while at the same time ensuring the environmental goals, is often termed the energy trilemma, as these three goals are partly contradicting.

To reach its main goal, CINELDI therefore seeks to balance the three goals related to the electricity distribution grid as explained in the following:

Economy:
CINELDI shall enable a socio-economic, cost-efficient realisation of the future flexible and robust electricity distribution grid and reduce the total distribution system costs compared to the "business as usual"-solutions by reducing operational (OPEX) and investment costs (CAPEX).

Environment:
CINELDI will pave the ground for increased distributed generation from renewable energy sources, electrification of transport and efficient use of electric power and energy.

Security of electricity supply:
CINELDI will ensure the security of electricity supply, comprising the energy availability, power capacity, reliability of supply and voltage quality, as well as the cyber security, safety and privacy – as important parts of developing the electricity grid of the future.

MAIN DELIVERABLES

The main deliverables from CINELDI are:

- Decision support methodologies and tools needed for the optimal planning and asset management of the future system.
- New cost-effective concepts and solutions for smart operations based on new emerging control and monitoring technologies and extensive real time monitoring.
- Methods and models for cost-effective integration of flexible resources in smart distribution grids, including business models on how to utilise this flexibility.
- New concepts and solutions for utilising flexible resources in ancillary services and for increased observability between the distribution and transmission systems
- Microgrid concepts, technologies and solutions for optimal design, operation, and integration with the distribution system.
- Roadmap and recommendations for the transition to the intelligent electricity distribution system of 2030-2040 in Norway.
- Knowledge base for grid owners and public authorities
- Training researchers and master students and transfer expertise to industrial stakeholders
- Efficient knowledge transfer through goal-oriented communication and user-involvement
- Promote business opportunities for technology providers.

RESEARCH AND INNOVATION STRATEGY

RESEARCH

The research in CINELDI targets the electricity grid situation in 2030-2040, 10-20 years after the deployment of Norway's first-generation smart meters (AMI) in 2019.

The research activities are designed to meet the main goal of CINELDI in close cooperation between the technologies power engineering, cybernetics, information and communication technology, supported by social sciences (socio-economics and consumer behaviour related to flexibility).

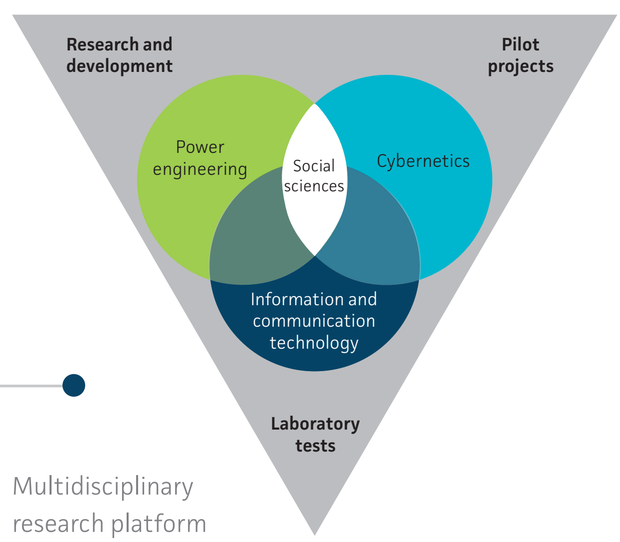
The research activities are organised in six research areas, represented by the work packages (WP):

- Smart grid development and asset management (WP1)
- Smart grid operation (WP2)
- Interaction DSO/TSO (WP3)
- Microgrids (WP4)
- Flexible resources in the power system (WP5)
- Smart grid scenarios and transition strategies (WP6)

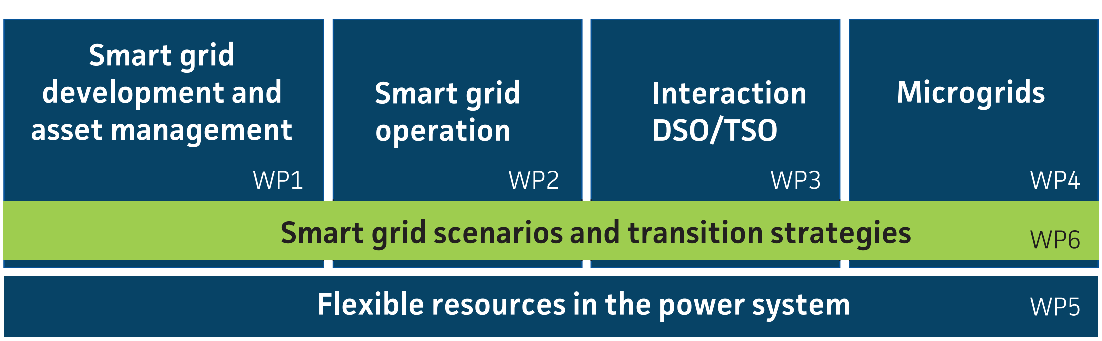
The WPs reflect the main aspects of power system operation and management and are tightly integrated to stimulate innovative ability at the electricity distribution level. This ensures that each WP addresses research questions of high relevance for industry and society, enable academic partners to work in close collaboration regardless of discipline and facilitate interaction and communication between research and industry partners.

The CINELDI multidisciplinary research platform consists of three pillars:

- Research and development
- Pilot projects
- Laboratory tests.



Multidisciplinary research platform



CINELDI WPs and how they are organised

Advanced basic and applied research will provide in-depth knowledge, methods, and tools that will be tested in laboratories, simulated environments and small-scale field pilots.

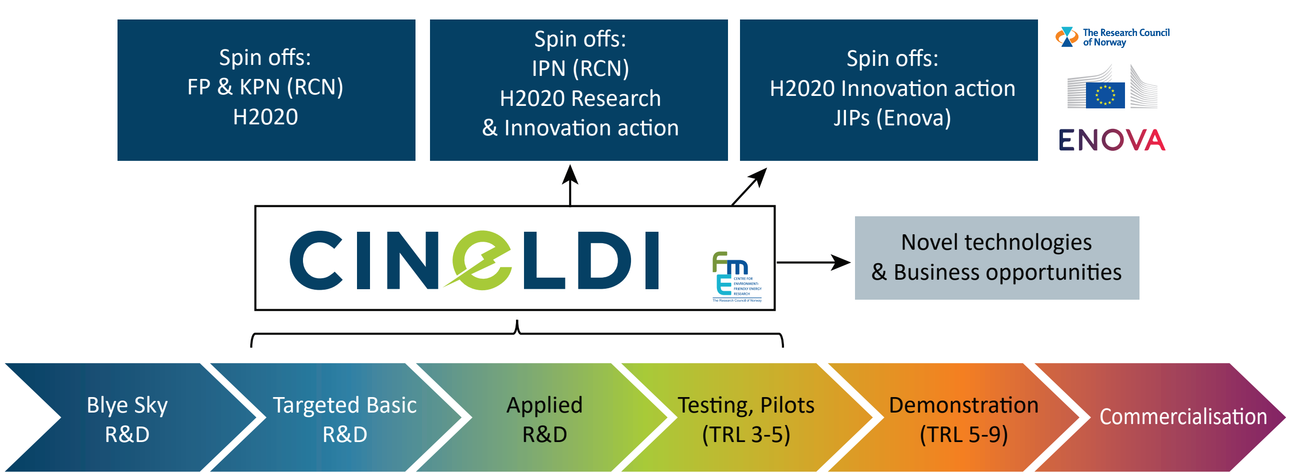
Active utilisation of use case methodology and research infrastructure including the Norwegian Smart Grid laboratory and living labs in pilot projects and laboratory tests are important parts of the research strategy and the multidisciplinary research platform, integrating active involvement from the industry partners.

INNOVATION

Innovation is a key factor to succeed with CINELDI and the Centre targets system innovation for the electricity distribution system.

CINELDI is positioned between targeted basic research and Demonstration (TRL 5-9) and novel technology & business opportunities.

Through working with user partners, CINELDI will identify new business opportunities and elevate pilot projects to new national and international spin-off projects along the whole value chain, in particular build-up capacity to succeed in H2020 projects with higher TRL levels (5-9).



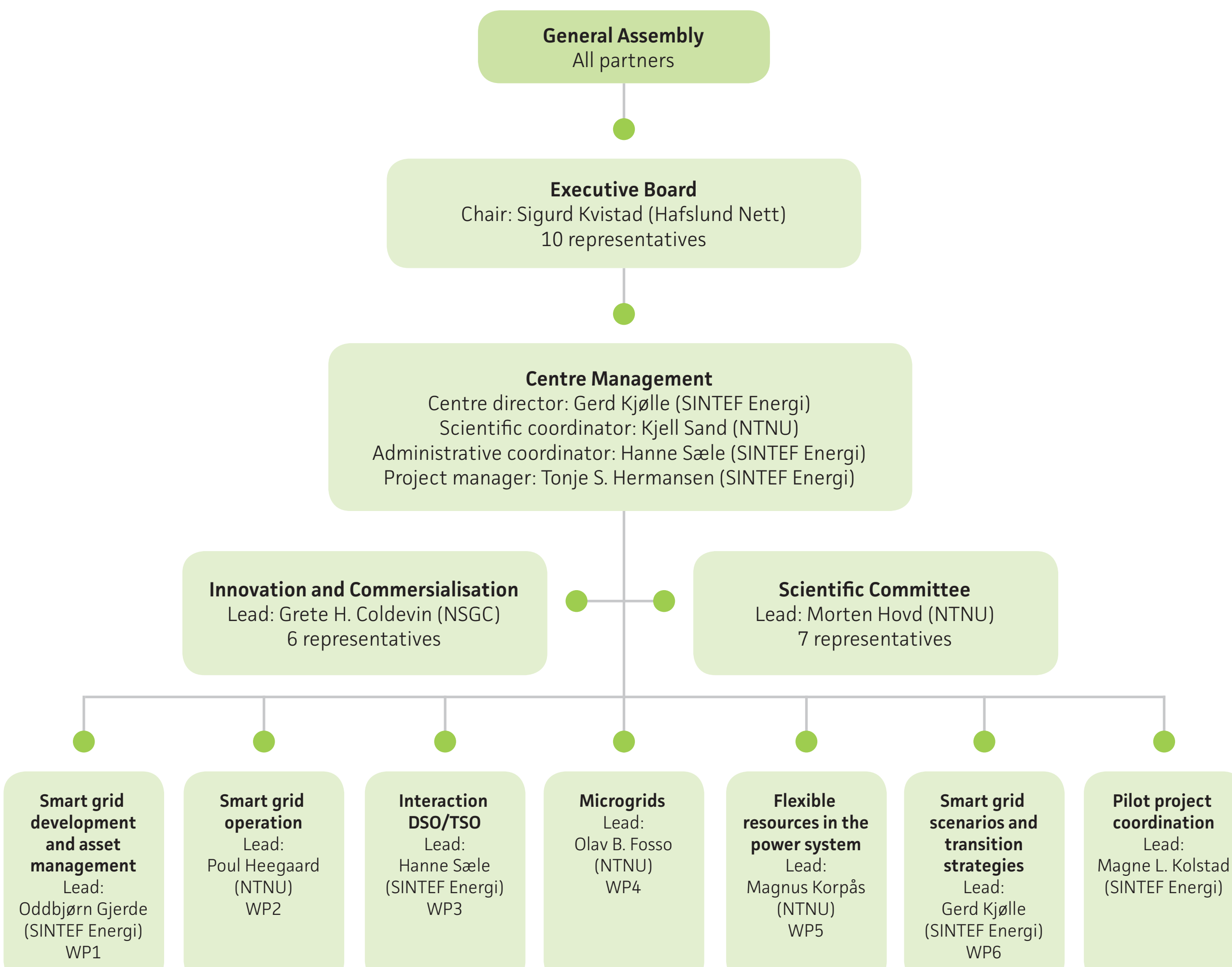
CINELDI innovations and Spin Offs

ORGANISATION

ORGANISATIONAL STRUCTURE

CINELDI is organised with

- a General Assembly (GA)
- an Executive Board (EB)
- a Centre Management with a Centre Director
- a Committee for Innovation and Commercialisation
- a Scientific Committee (SC)



Outline of governance structure for CINELDI per 2018*

*Henning Taxt is WP2 lead from March 1, 2019.
*Magnus Korpås is Scientific Committee lead from 2019

PARTNERS

Research partners

SINTEF Energi AS

NTNU

SINTEF Digital

Industry and vendor partners

DISTRIBUTION SYSTEM OPERATORS

Hafslund Nett AS

Skagerak Nett AS

Lyse Elnett AS

BKK Nett AS

Eidsiva Nett AS

Norgesnett AS

Helgeland Kraft AS

Agder Energi Nett AS

Istad Nett AS

NTE Nett AS

SFE Nett AS

Nordlandsnett AS

Haugaland Kraft Nett AS

TRANSMISSION SYSTEM OPERATOR AND MARKET OPERATOR

Statnett SF

Nord Pool AS

VENDORS

ABB AS

Powel AS

Rejlers Embriq AS

Aidon Norge

Eltek AS

Smart Grid Services Cluster

MEMBER ORGANISATIONS

Energi Norge AS

KraftCERT AS

The Norwegian Smart Grid Centre

AUTHORITIES

Norges Vassdrags-
og energidirektorat

Direktoratet for samfunns-
sikkerhet og beredskap

Nasjonal
kommunikasjonsmyndighet

COOPERATION BETWEEN PARTNERS

CINELDI had a total of 30 partners in 2018, including 27 user partners. In 2018, partners have participated in several workshops, to discuss activities and contribute to the research in CINELDI.

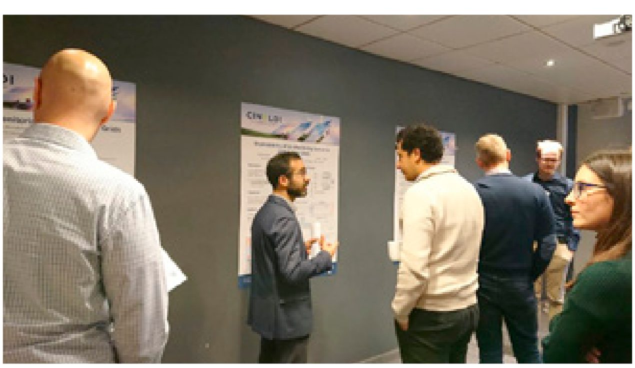
In May, WP4 arranged a workshop on microgrids and WP6 arranged the fourth workshop on developing scenarios for the future distribution grid (WP6). In the workshops, the partners were actively involved in group work. On June 4th, a workshop was arranged on smart grid development and asset management (WP1). Preliminary results were presented and discussed with partners. On June 5th, there was a workshop on smart grid operation (WP2), including group work. A workshop on DSO/TSO interaction and flexible resources was arranged June 12th (WP3 and WP5), including group discussions.

The largest gathering of user partners was on the CINELDI days, which were held October 23-24. The aim of these days was to present results from the research, to present user partner projects that may be included as pilot projects in CINELDI, and to strengthen user involvement and interaction in the consortium. A poster session was arranged where the PhDs and postdocs in CINELDI presented their work for the partners. The pilot project "New protection concept" was awarded the first CINELDI prize.

All WPs have actively used the expert groups in the development of the work plans for the coming year(s). The expert groups have also been involved in planning partner workshops.

In all WPs, there is cooperation between the R&D partners, as all work packages are multidisciplinary organised. The user partners are involved in several case studies as part of the research activities, among others "risk identification and visualisation of vulnerabilities in self-healing grids", as described in the Selected cases part of the report.

Pilot projects are also an arena for cooperation between the different R&D partners and user partners, see section on "Pilot projects in CINELDI".



Pictures from CINELDI days in 2018.

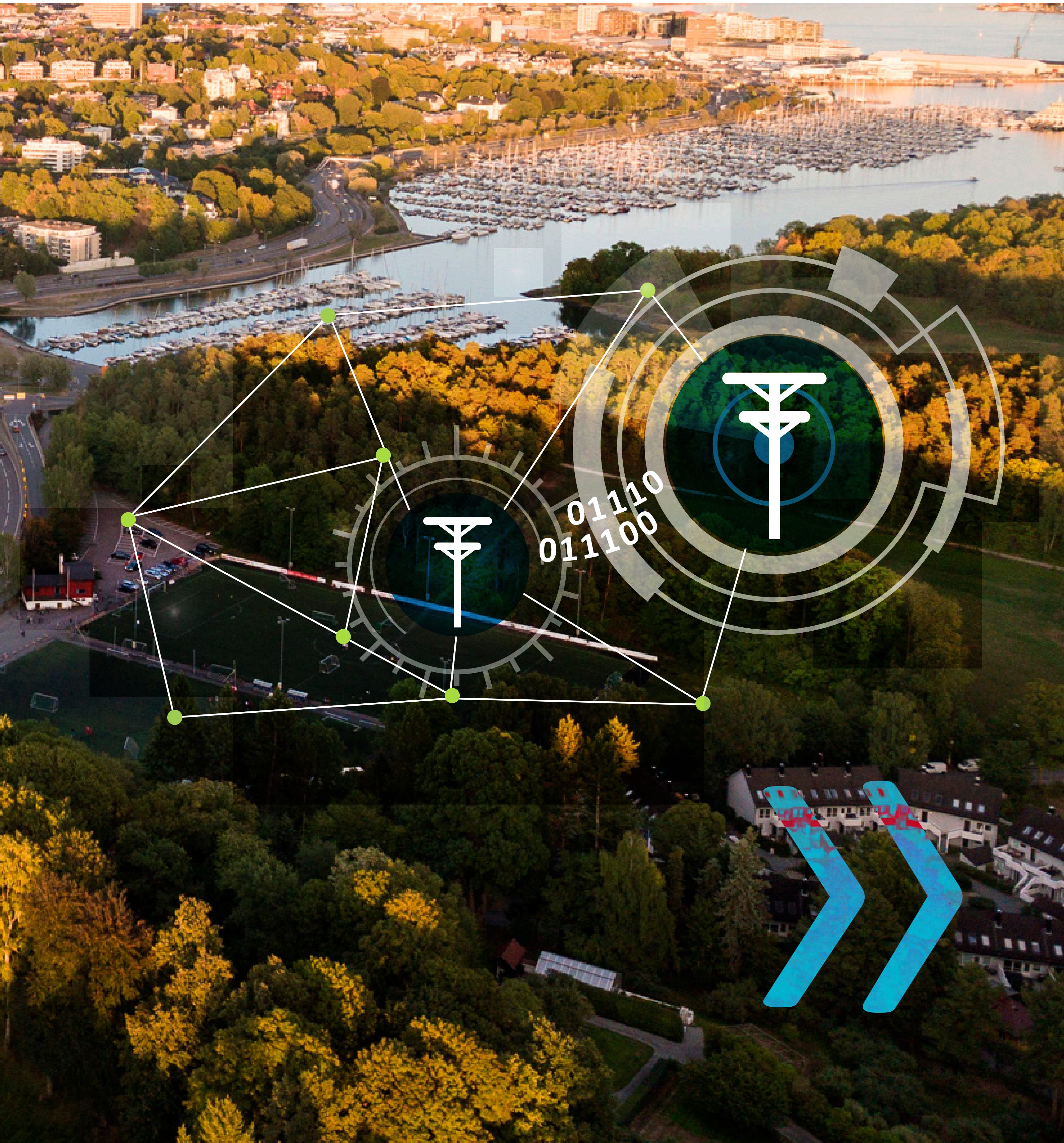
RESEARCH ACTIVITIES AND RESULTS

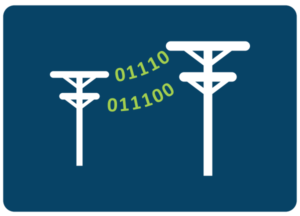
The research in CINELDI addresses advances of electricity distribution system planning, operations and management, where new and emerging topics are emphasised, e.g., utilisation of innovative sensors and smart components for monitoring and control, microgrids and utilisation of the flexible resources inherent in distributed generation, consumption and electricity storage, and cyber security. The centre will also develop scenarios for the future intelligent distribution grids in Norway.

The Norwegian Smart Grid Laboratory is utilised in several activities already, both in master and PhD-projects as well as by other tasks and researchers. So far, CINELDI has 8 PhD students and 2 post-doctoral researchers integrated in the work packages, as well as many master projects.

Some highlights from the research in 2018 are presented in the following.

SMART GRID DEVELOPMENT AND ASSET MANAGEMENT (WP1)





The primary objective of CINELDI's WP1 is to develop decision support methodologies and tools needed for the optimal planning and asset management of the future robust, flexible and intelligent distribution system.

The *expected impact* is a more efficient grid through better utilization of existing and new infrastructure, more target-oriented investments, and better control of risks.

ACTIVE DISTRIBUTION GRID PLANNING

In 2018, the first steps have been taken towards establishing a planning methodology for the future distribution grid. The future distribution system will be penetrated by new technologies such as distributed generation including prosumers and more power intensive loads, resulting in new load and generation patterns. At the same time new sensors and the introduction of IoT and new communication systems are expected to make massive amounts of operational data available. Many of the changes will be customer driven, and new uncertainties will emerge for the distribution system operators, making planning of "future proof" distribution systems more challenging. These changes this will simultaneously offer new planning options. Examples are electrical energy storage, microgrids, demand response schemes and vehicle to grid. Distribution grid planning will rely on measures taken during system operation to a much larger extent than before. The above described transition may be additionally speeded up by the fact that the utilities need to deal with an ageing grid exposed to continuously increasing weather and climate related stresses.

To utilise operational measures in the grid planning, new methods to evaluate active distribution systems as alternatives to grid reinforcements need to be developed. A literature study on planning methodologies and tools for the future distribution system has revealed that considerable work has been done already, and an important reference is the CIGRÉ C6.19 Working Group report[4] on planning and optimisation methods for active distribution systems. This report assesses the various requirements to facilitate the transition towards active distribution systems. A general framework for active distribution system planning is outlined, taking into consideration several novelties such as probabilistic load and generation data models based on real data from smart meters, probabilistic grid calculations resulting in stochastic representation of the nodal voltage and branch current variables and the use of active management before exploring traditional grid solutions. A multi-objective approach is suggested as the impact of several new technologies and control architectures required by the active distribution system is hard to characterise exclusively in terms of grid costs. This work will constitute a valuable basis for the further work in CINELDI, dealing with identified gaps related to different planning aspects such as load and generation forecasting, probabilistic load flow analysis, flexibility and microgrids as alternatives or

4 Pilo, F. et. al, "Planning and Optimization Methods for Active Distribution Systems," CIGRE, working group C6.19, 2014.

supplements to investments, risk assessment in the future combined power and ICT system, cyber security in power systems, reliability analysis, voltage quality analysis and maintenance and reinvestment analysis. Currently, a case study is being set up in the SPREAD planning tool in a cooperation with a few of the utilities represented in CINELDI and the University of Cagliari. The aim is to analyse alternatives to grid reinforcements in a representative Norwegian grid.

COMBINED POWER AND ICT SYSTEM RELIABILITY

Many of the new active distribution system options are depending on reliable and secure communication as well as robust ICT systems for monitoring and control. Simultaneously new cyber security threats and vulnerabilities are introduced. Work relevant to risk assessment in the future combined power and ICT system has already been carried out, and an approach to identification and modelling of cybersecurity risks in the context of smart power grids is proposed. The aim is that the risk model can be presented to decision makers in a suitable interface, thereby serving as a useful support for planning, design and operation of smart power grids. The approach is tested on a realistic industrial case with a distribution system operator responsible for hosting a pilot installation of the self-healing functionality within a power distribution grid. See "Risk identification and visualisation of vulnerabilities in self-healing grids" in the Selected cases part of the annual report for more information.

The same approach is currently being applied to study a pilot on digital substations, to gain even more experience with it.

Further, to maintain a stable operation in the future distribution system, real time monitoring and control is increasingly needed. In WP1, work has been carried out to develop a method and tool for analysing the performance and dependability of advanced communication technologies, based on Stochastic Activity Network modelling. A novel software tool is developed and employed to analyse the impact of communication failures on the state estimation of a distribution grid. The application of the tool and its capabilities are demonstrated through a case study with promising results.

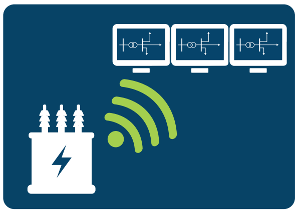
REMOTE DIGITAL INSPECTION

The future ICT and communication systems will at the one hand be an important provider of asset condition data and on the other hand represent a new asset to be managed optimally in combination with the power system. As an example, in today's regime all distribution system substations are physically inspected once a year. CINELDI WP1 is aiming to make inspections more efficient by extending the inspection interval through utilising the information from existing and new sensors, without jeopardising safety. Currently, work is going on to specify a pilot on digital sensor-based remote inspection of substations in a cooperation between the research partners and some of the industry partners (vendors and utilities).

STUDENT WORK

Altogether five master students finished their specialisation project in cooperation with WP1 in 2018. One student has been working with load patterns for distribution system planning, three students have been working with different questions related to impact on the distribution system from increasing penetration of electric vehicles, and one student with visualisation in next generation asset management. The work is integrated into the work package and will continue as master theses in 2019.

SMART GRID OPERATION **(WP2)**



The *objective* of WP2 is to develop and test a set of new concepts and solutions that optimally utilise new emerging control and monitoring technologies capable of exploiting extensive, real time monitoring to/from all assets and network customers and flexible resources. The *expected impact* is a more flexible operation of the distribution grid, contributing to cost reductions, enhanced energy efficiency and improved system reliability and security, as well as standardised solutions.

MODELLING CONSEQUENCES ON SECURITY OF SUPPLY BY EXTENSIVE USE OF IEDS

When introducing Intelligent Electronic Devices (IEDs, with microprocessors and communication interfaces) we get new possibilities for operation support (censoring, remote control, self-healing), but also a set of new fault cases and failure modes that need to be carefully investigated. The work on a theoretical model (analytical and/or simulation) for a system of such IEDs is started and will be continued in 2019. The goal is to be able to quantify the effect on security of electricity supply of different constellations of sensors and controllers, and distributed vs centralised control and self-healing solutions.

EVALUATING LOCAL DISASTER RECOVERY STRATEGIES

Different options for temporal replacement/relocation of communication equipment are investigated, to maintain a minimum of communication service after a disaster, for example by temporarily replacing damaged nodes by emergency nodes. Communication services are of critical importance in situations where a lot of coordination needs to be done, e.g., restore power supply. A framework is proposed to evaluate different node replacement strategies, based on a large set of representative disasters.

DATA GATHERING AND -ASSEMBLING FROM SEVERAL SMART METER HAN PORTS

The objective of the master thesis work was to implement an embedded system enabling the real-time data gathering and -assembling from the HAN (home area network) ports of distributed smart meters. The system consists of a tiny embedded system for reading the output of the HAN port and interpreting the data, a 4G connection to a cloud service for data transfer using existing tele-communication infrastructure, and a simple graphical user interface for displaying the voltage as a function of location along the line.

USE CASES FOR SMART GRID OPERATION

Based on the previously defined topics (in 2017) several Use Cases have been developed in close collaboration with CINELDI partners, presented in a webinar "Introduction to Use Case Methodology", and a joint workshop on the use and misuse cases. One of the use cases "State of the art of applying machine learning on Smart Grid data" about application of machine learning for outage management, has been elaborated and accepted for presentation at the CIRED 2019 conference.

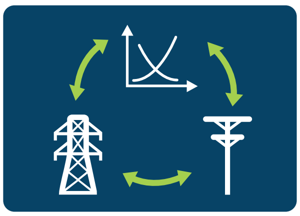
MISUSE CASES

Misuse cases for communication interoperability, ICT security and privacy (CIIP) were developed, based on a review of existing CIIP use cases, input from the other use cases, and from a workshop with participating experts where the focus was on smart distribution grids and manipulation of communication networks. Two master students completed their thesis on security of smart meters and IoT devices for the electricity grid.

A NEW CONCEPT FOR PROTECTION IN DISTRIBUTION SYSTEMS

The experimental testing of the Hafslund new protection concept, started in 2017, has been extended to cover a broad range and variance of fault situations. This work continues in 2019 to provide an extensive test coverage with laboratory testing, simulations in MATLAB/Simulink, hardware-in-the-loop testing, and finally the goal is to do real-life implementation in a pre-determined part of Hafslund's distribution grid where the physical infrastructure is already in place.

INTERACTION DSO/TSO **(WP3)**



The *objectives* of WP3 are to develop concepts and solutions for utilizing flexible resources (DER)[5] in different market products and ancillary services, for increased observability between the distribution and transmission systems and business models regarding utilisation of customer flexibility (DER).

The *expected impact* from these objectives is improved interaction DSO-TSO to benefit the total power system, especially by enabling DER flexibility to all voltage levels.

USE OF FLEXIBLE RESOURCES IN GRID OPERATION – TODAY AND IN THE FUTURE (2030/2040)

In the beginning of 2018, a survey was sent out to the DSOs in CINELDI, with the objective to map the status of interaction DSO/TSO and the use of flexible resources in the operation today, and input related to what is expected in the future (2030/2040). To be able to discuss the transition towards this long-term period, the assumed starting point has been a survey mapping today's status and future expectations about the DSO/TSO interactions, and focusing especially on how and how much flexible resources are and will potentially be utilised in the power system operation and also on what kind of information it is necessary to monitor.

According to the survey, the use of flexible resources today is mainly related to disconnection of unprioritized demand units that have an agreement for disconnection through a reduced grid tariff. Typically, these loads can be disconnected for an unlimited period (disconnected in periods with temporary problems with limited grid capacity), and the customers have alternative energy carriers to use when the electric load is disconnected. Based on experience, this agreement for disconnection is seldom in use.

In the future, the DSOs expect that there will be an increasing focus on flexible resources, and not only to be used in periods with limited grid capacity in the power system. Due to technology development combined with reduced costs for different technologies (for example PV panels, electric batteries and communication and control technologies), flexible resources are evaluated as a new source to be included in cost efficient operation of the power system. In other words, it is expected that a wider variety of flexible resources will be available in 2030/2040, and that these will also be used in normal operation of the grid.

The evaluation of future use of flexible resources was combined with the suggestion from EU FP7 project ELECTRA IRP, for a future (2030+) decentralized control architecture (Web-of-Cells) for balance (including frequency) and voltage control, as opposed to the current centralized control approach typical of Transmission System Operators (TSOs).

5 DER = Distributed Energy Resources = Energy storage, distributed generation from renewable sources and demand response.

EUROPEAN LEGISLATION RELATED TO THE DSO-TSO COOPERATION

Important topics for DSO-TSO cooperation in the European legislation has been studied, in cooperation with the SmartNet project. The study is structured around the following topics of interest: Market layer, Bidding layer and Physical layer. These topics of interest were evaluated based on more than 40 different documents as position papers, strategies, roadmaps and legislation/regulation (EU Directives, Network guidelines).

EVALUATION OF USE CASE (REPOSITORY) AND RELEVANT MINI-SCENARIOS

Existing use cases have been evaluated, with the purpose to get an overview of use cases from other projects, covering topics relevant for WP3. 213 use cases gathered from EPRI, ELECTRA IRP and DISCERN were evaluated. Both EPRI and DISCERN refer to use case repositories, which gathers use case and sort them by topic. 86 use cases were evaluated as relevant for WP3.

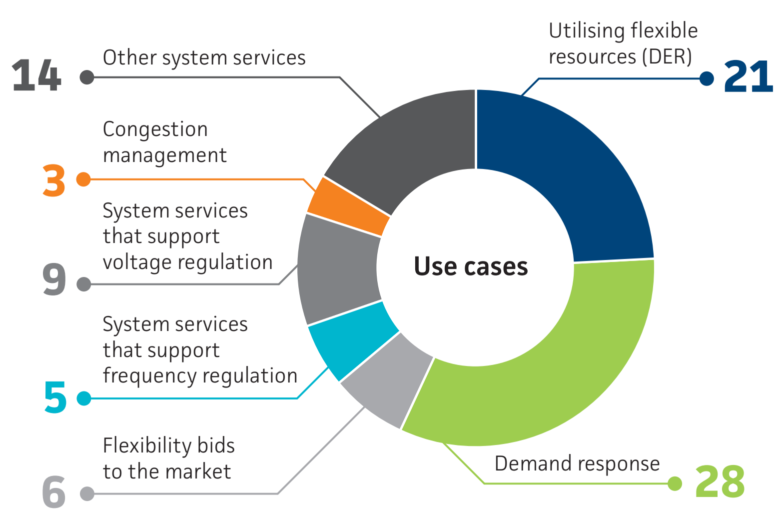
The use cases were sorted according to the following categories, and the number of relevant use cases within each category are presented in brackets:

1. Utilising flexible resources (DER) (21 use cases)
2. Demand response (28 use cases)
3. Flexibility bids to the market (6 use cases)
4. System services that support frequency regulation (5 use cases)
5. System services that support voltage regulation (9 use cases)
6. Congestion management (3 use cases)
7. Other system services (14 use cases)

At the end of the year work for evaluating the mini scenarios from WP6, related to the focus within WP3 was started and will be continued in 2019. This work will be basis for development of the future use cases: use of flexible resources for balancing, handling bottle-necks and voltage regulation.

TECHNICAL AND PRACTICAL APPROACHES TO DEFINE NEW DSO-TSO INTERACTION SCHEMES

A literature study with the objective to study and report the technical and practical approaches used in the literature to define new DSO-TSO interaction schemes has been performed. Most of the reviewed research activities focused on devising DSO-TSO joint optimal flexibility dispatching techniques. There is limited research regarding markets' influence and data privacy issues with regards to DSO-TSO interactions. The reviewed literature also indicates that there are significant numbers of demo activities testing the merits of increased data exchange between TSO and DSO. Based on the literature study, summary of the contemporary DSO-TSO interactions and the recommended future practices are presented.



MICROGRIDS (WP4)

The objective of WP4 is to develop concepts, technologies and models for microgrids and their interaction with the distribution system.

The *expected impact* is a contribution to cost-efficient and robust integration of microgrids with the distribution grid, and a contribution to the integration of more distributed and renewable energy resources (DER) in the system.

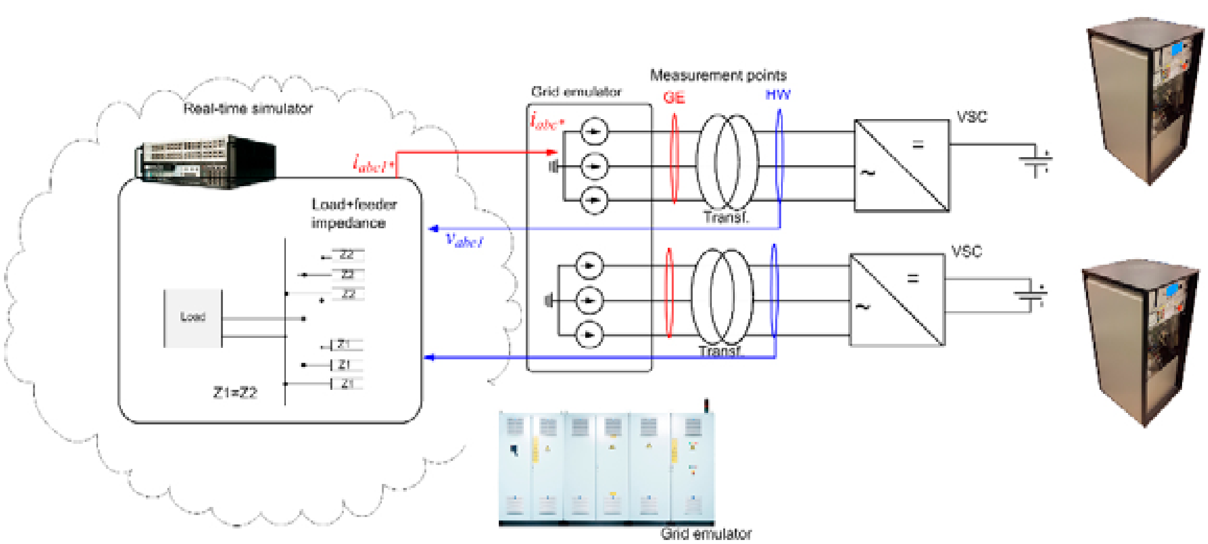
STATE OF THE ART WITHIN MICROGRID DEVELOPMENT

Activities related to assess the state of the art internationally and relate this to challenges within the setting of CINELDI were initiated in 2017. These activities were concluded in 2018 in the memos:

- Mikronett i Norge – Muligheter og utfordringer
- Microgrid protection – challenges and solutions
- Fault responses of inverter-interfaced DER – literature review

DEVELOPMENT OF LABORATORY INFRASTRUCTURE

An essential part of the activities within WP4 in 2018, has been the development of a laboratory infrastructure to be used to facilitate research and development activities within CINELDI as well as to do externally funded projects. A setup in the smart grid lab that is a building block for the proposed "Real-time power hardware-in-the-loop simulation platform to evaluate ancillary services in microgrids" has therefore been implemented. The setup is two parallel inverters operated in island mode for feeding a linear load. The load is emulated using the grid emulator and the real time simulator for providing more flexibility in terms of the feeder impedance/load that can be connected to the system. At the moment, the setup is able to operate one converter with an emulated load, a synchronisation mechanism is needed to connect the other converter. A figure is provided for illustration.



PhD/Post Docs – INTERNALLY AND EXTERNALLY FUNDED

WP4 currently has two PhD-students funded from CINELDI where one is working on the task Microgrid Protection with the perspective of communication and use of 5G technologies, while the other is in the task on Ancillary Services and Energy Routers. The candidates are progressing well and have publications accepted and under review. To strengthen the activities within WP4, externally funded PhD and Post docs have been recruited to work with Microgrid related topics. One PhD-student and one Post doc are working within dynamic interaction in systems with high penetration of Power Electronic converters. Both positions are on strategic funding from NTNU. One PhD-student funded through SINTEF Energy Research/ Norwegian Research Council is working within planning in systems with distributed intermittent resources and storage devices. The experience with techniques developed for large-scale hydro scheduling is a core for the activities. An exchange PhD-student funded by the Norwegian Research Council coming from Shanghai Jiao Tong University, China, working within planning and operation of microgrid systems is on a one year stay at NTNU while a PhD-student from Universidad Tecnica de Pereira, Colombia, is working on control strategies for non-linear systems during his seven-month stay at NTNU. The external resources have made it possible to work on a broader scope and to build a more solid foundation for the future work within WP4 Microgrids.

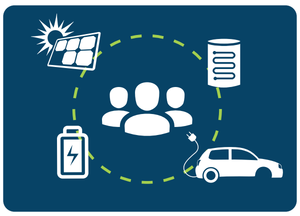
MSc AND PROJECT STUDENTS – WP4 RELEVANT ACTIVITIES

A priority within WP4 has been to have a close collaboration with MSc-students at NTNU to provide interesting and challenging research activities within microgrids. The activity of one student is equivalent to eight months full-time work. Five MSc-projected were concluded in the spring 2018. In the autumn 2018, seven students were recruited for the project continuing in a MSc-project finishing in 2019. These projects cover all major activities of WP4.

DISSEMINATION AND PUBLICATIONS

Several conference and journal papers have been published related to the WP4 from researchers and internally and externally funded PhD-students and Post docs. Additionally, a significant number of papers are in the review process in internationally recognised journals. Five MSc theses were completed in June 2018 and seven student projects completed in December 2018. The student projects are continued in the spring 2019 and will be completed as MSc-thesis in June 2019.

FLEXIBLE RESOURCES IN THE POWER SYSTEM (WP5)



The overlaying objective of WP5 is to develop methods and models for cost effective integration of flexible resources in smart distribution grids.

The *expected impact* of the research is to contribute to improved efficiency of the system operation when utilising flexibility as an important asset in the power system.

GRID FLEXIBILITY CATEGORISATION AND MODELLING

Electric vehicles (EVs) in Norway and the potential for demand response

Work has been performed focusing on the consequences of the increasing share of electric vehicles and the potential for demand response and flexibility in charging. Results are based on a survey performed among households with electric vehicles and meter data of the energy consumption from charging of a selection of the most common electrical vehicles in Norway.

According to the survey most of the charging was performed in the afternoon and during the night, and approx. 50% of the households charge their EV from a normal socket (10 A). To map the potential for flexibility in time of charging, the respondents were asked about their willingness to postpone the time of charging from day/afternoon to night (hour 21-05). The respondents further supported the idea that if this shift in charging time had no negative consequences for the user, 90% were willing to postpone the time of charging, but if this reduced the driving distance the next day to 80%, the share of positive respondents was reduced to 56,5%. 38,2% of the respondents were positive to this change in time of charging if they save 200 €/year. A lesser amount (26,4%) of the respondents were positive if the savings are reduced to 50 €/year.

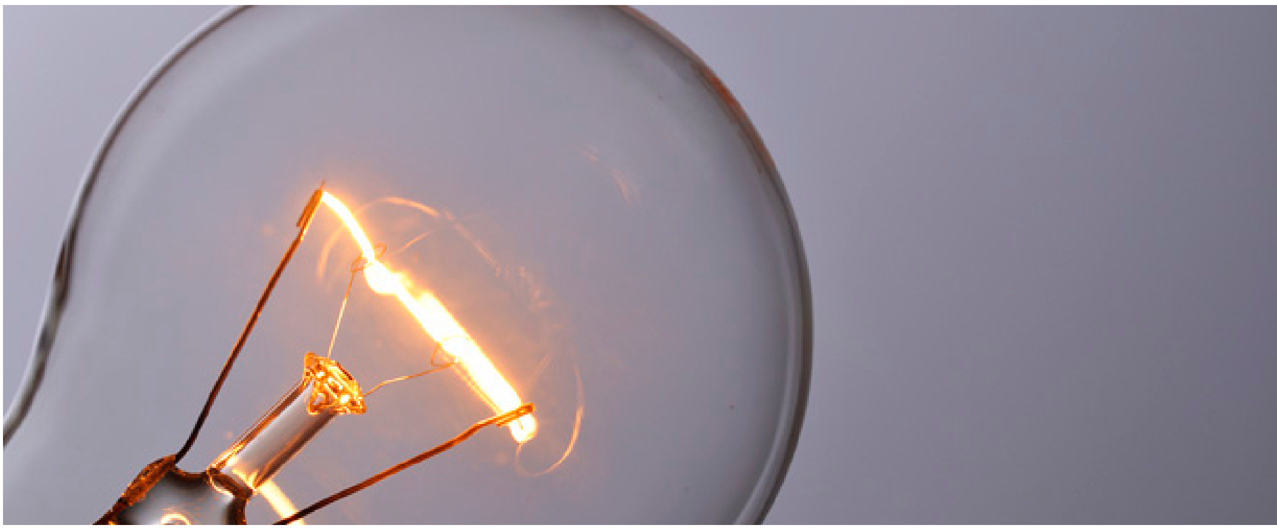
Households' potential for flexibility

A survey among a representative sample of house-holds has been performed, evaluating the households' potential for flexibility. According to this survey 3 out of 4 households will delay the start of their washing machine and dishwasher until later the same day, on a cold day when there is limited grid capacity available. 2 out of 3 households can accept remote control of their water heater (as long as they do not get cold water) on such a cold day. Every second household will reduce their electricity consumption if this can help others to get electricity back after an outage.

Data-driven Household Load Flexibility Modelling: Shiftable Atomic Loads

This work describes a flexibility modelling method for atomic loads, which is based on high resolution appliance measurement data. Shiftable atomic loads are loads that can be shifted but once they start, they cannot be interrupted (cloth washing machines, dryers and dishwashers).

The practice of shifting the load from one hour to another is not simply cutting the load of the previous hour and adding it to the new hour. Rather, especially for shiftable atomic loads, flexibility modelling requires a careful study of both the consumption profile of the individual loads to be shifted and the temporal probability of use profile of the appliance in stock of households. Atomic loads cannot be interrupted



and hence only the starting time can be shifted. This method can be used to quantify the flexibility potential of shiftable non-interruptible appliances.

The presented method will inform stakeholders how much power (kW) they can reduce by shifting the potential operation of the appliances. The activation of such flexibility resources, on the other hand, requires its own in-depth investigation as it may depend on the availability of communication channels to both customers and appliances, the willingness of customers, the market arrangement and the smartness of the appliances. Also, smart activation of the resources shall be executed to avoid rebound effects; for example, by distributing the shifting of a group of appliances over time instead of executing all resources at once. The rebound effect mainly arises from an increase in consumption due to the superimposing of shifted appliances on top of the already operating appliances. Hence, rather than spreading the shifting of the appliances overtime, one has to observe the probabilities of start operation for the next hours to decide the appropriate hour to shift to.

Analysis of Future Loading Scenarios in a Norwegian LV Network
The aim of this analysis is to support the realistic understanding of the potential network loading and power quality related problems coming in the network and to what extent flexibility resources could reduce or eliminate those challenges. An LV test network supplying residential area from 22 kV/ 230V secondary substation in Steinkjer in central Norway is used for the analysis.

Sizing electric battery storage system for prosumer villas
A simple energy flow model is developed where the battery is utilised to reduce the peak load from the villas (Skarpnes). The analysis show that there is a significant reduction in the daily peak load distribution by the use of battery storage systems. However, the peak-reduction effect is levelling out for larger storage capacities as measured relative to the consumption level of the villa.

CUSTOMERS' INVOLVEMENT IN FLEXIBILITY

There is an ongoing PhD work with the objective to improve the understanding of how different grid customer groups can and will contribute with flexibility, and how DSOs and other stakeholders - especially retailers and aggregators - can utilise this knowledge to improve their services and profitability. Main research activities include in-depth studies on mechanisms and incentives for motivating customers to contribute with flexibility; analysis of the role of intermediaries which must be incentivised to facilitate or take up Demand Response (DR) services, contract design, and the related technological infrastructures and DR technologies to support the commercial products and new business models demonstrating the profitability of DR in the future power market.

A pre-study has been performed including interviews with 15 stakeholders from the industry, research etc., to study the definition of the term "flexibility mechanisms", and what they expect of future development within this area. This has been followed up with household interviews, where some have advanced flexibility systems installed (Stavanger), and a larger group has no such systems (Trøndelag + indre Østlandet). These interviews will generate data for further PhD work.

VALUE OF FLEXIBILITY

The impact of flexible resources on the security of electricity supply

A literature survey on the impact of flexible resources on the security of electricity supply (SoS) has been performed. The flexible resources that are considered are the following distributed energy resources: demand response (DR), stationary distributed energy storage systems (ESS), electrical vehicles (EV), and distributed (primarily photovoltaic, or PV) generation. Microgrids (MGs) are also considered to some extent. The survey distinguished between four aspects of security of electricity supply: energy availability; power capacity; reliability of supply; and power quality, which includes the voltage root mean square average value, the voltage waveform, and frequency quality.

In general, the requirements for services from flexible resources must be seen in relation to the time scales of the SoS issues they are addressing. Frequency regulation services to improve frequency quality operate on different time scales, and most flexible resources are capable of providing some of these services. But for fast frequency reserves to avoid rapid drops in system frequency due to loss of power injections, battery energy storage and demand response for certain loads are believed to have the greatest potential due to their short response time. All flexible resources except for demand response can provide voltage control. Other examples of potential services for improving power quality include phase balancing and damping of harmonics.

SMART GRID SCENARIOS AND TRANSITION STRATEGIES **(WP6)**

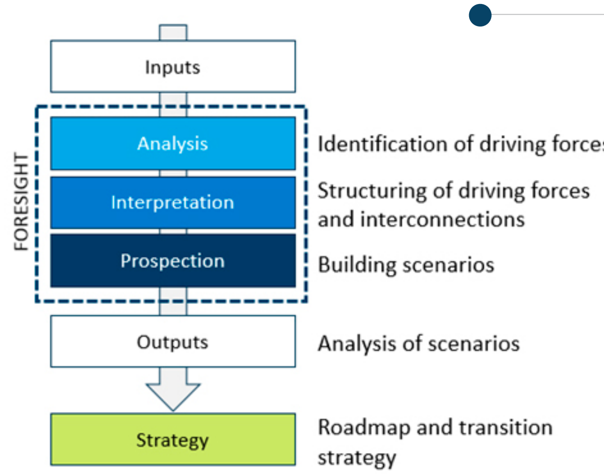
The objective of WP6 is to develop a credible set of Smart Grid visions and scenarios as input to the other work packages in CINELDI, and as a basis for fostering new ideas and innovation. WP6 will also develop guidelines and recommendations for the transition to the flexible, robust, and cost-efficient electricity distribution system of 2030-2040, by integrating the results and findings from the other work packages into a holistic strategy.

The *expected impact* is twofold: 1) a structured multidisciplinary research, providing results that are robust to external requirements and opportunities for the future distribution system, and 2) that these strategies and recommendations will be used by the electricity industry to update their local strategies thus enabling the transition to happen.

FORESIGHT PROCESS DEVELOPING SCENARIOS

The future grid anno 2030-2040 will be a complex system-of-systems, incorporating various intelligent devices and technologies. On the cyber-physical electricity distribution system level, the interactions between various technological, economic, organisational, and human factors add complexity that needs to be addressed in a holistic and coordinated way in order to support the system innovation.
WP6 seeks to identify the main drivers, barriers and enablers for this system innovation and based on this, develop a set of credible scenarios for the electricity distribution system in Norway. System innovation is here defined as a co-evolution of system-level technical, social and regulatory changes.

This work is performed as a foresight process through workshops and meetings gathering all partners in CINELDI, supported with literature surveys and further studies. Four workshops have been arranged during 2016-2018, performing stakeholder analysis, identifying drivers, barriers and enablers, developing mini scenarios and discussing the direction of the main scenarios. The foresight process and the implemented steps so far are illustrated in the figure:



In the two first steps of the foresight process, the driving forces for intelligent electricity distribution system innovation are identified and structured, and sorted into the three levels: megatrends, external driving forces and grid related driving forces.

REPOSITORY OF MINI SCENARIOS FOR THE FUTURE DISTRIBUTION SYSTEM

The driving forces further give the foundation for developing scenarios or alternative futures. The first step is to develop mini scenarios. *A mini scenario is a probable event, development or action of significance for the future electricity distribution system.* It is related to one or more driving forces.

In total, 109 mini scenarios are developed and collected in a repository. Examples of mini scenarios and their possible impact on the grid performance, are given below. The impact is shown with a description and a colour code:

Red	The mini scenario has a negative impact on the grid performance
Yellow	The impact on the grid performance is uncertain and can be both positive and / or negative
Green	The mini scenario has a positive impact on the grid performance
White	The mini scenario has no direct impact on the grid performance

"From peak power to stable loads"

Electrification of transport causes power challenges to the grid due to simultaneous fast charging. The ferry companies make large investments in on-shore battery packages with extra capacity. This results in stable load from the grid side, and possibilities for the ferry companies to provide flexibility / grid support in high load periods and fault situations.

Impact on grid performance	
Security of supply (Green)	Batteries are utilised to increase the security of supply.
Economy (Green)	Decreased CAPEX (defer investments)
Cyber security (White)	-
Safety (Yellow)	It may be challenging to know if the grid is energised or not when batteries can feed the grid. This must be solved to ensure personnel safety.

"Microgrids for all"

Many neighbourhoods are organised as microgrids. With heat pumps and distributed generation, the power and energy demand in the connection point is reduced. Several microgrids choose to go off-line, and the number of customers connected to the distribution grid is decreasing.

Impact on grid performance	
Security of supply (Yellow)	End-users may experience decreasing security of supply due to off-grid solutions
Economy (Yellow)	Uncertain revenue for the grid company
Cyber security (Yellow)	Local solutions (+), but more automation (-)
Safety (Yellow)	Must be handled by the local community itself

A small survey was performed among DSOs to gain insight into how they prepare for the uncertain future and how they may utilise the results from the foresight process. Some of the DSOs have already taken results from this foresight process in use in their strategic processes. To prepare for the uncertain future the DSOs focus on the following:

- Recruitment and competence building, for instance in data science
- Build new knowledge through new demonstration/ pilot projects
- Prepare for better utilisation of existing and new data
- Utilise the new knowledge to improve the work processes in grid management.

This work is described in a scientific paper "Driving forces for intelligent distribution system innovation – results from a foresight process", to be presented at CIRED 2019 in June in Madrid.

PILOT PROJECTS IN CINELDI

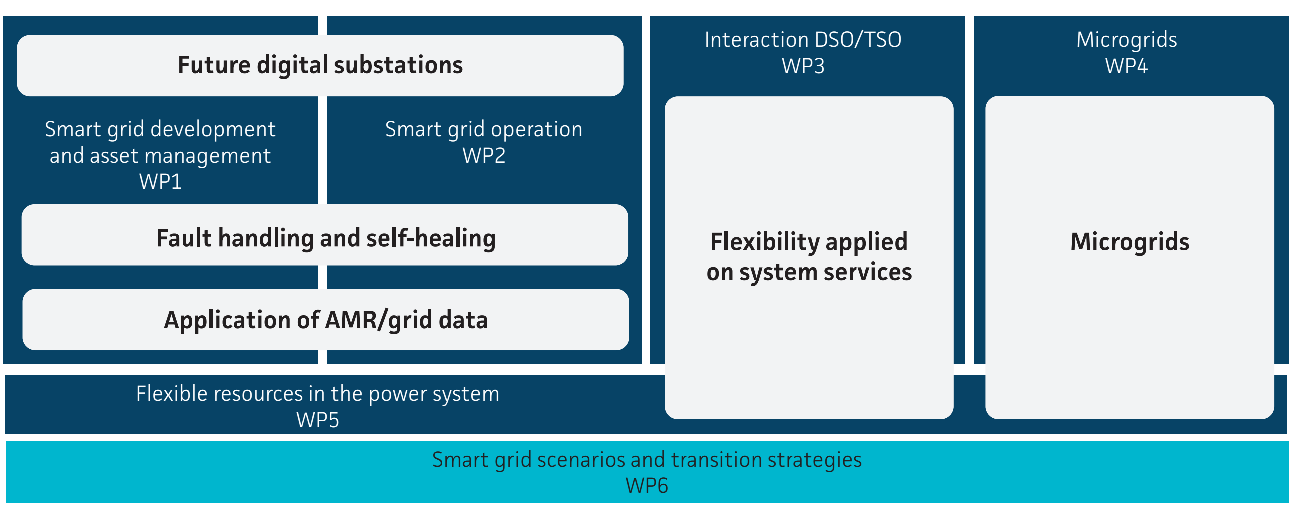
CINELDI will develop knowledge, methods, and tools that will be tested in laboratories, simulated environments, and small-scale field pilots. The pilot projects are as such important parts of CINELDI and will be an integrated part of the research and development in the FME.

Pilot projects are an important arena for involving the CINELDI user partners in interaction with the research partners. Pilot projects will contribute to system innovation for the distribution grid, and the goal is to test and verify technologies and solutions for the future grid under real conditions, at the Norwegian Smart Grid Laboratory and in "living labs", i.e. in the real distribution grid. The work is also carried out in cooperation with the Coordination Committee for Demo Norway in the Norwegian Smart Grid Centre. Pilot projects will help create new ideas and innovation from CINELDI.

CINELDI has decided on five priority areas for pilot projects. Each of the priority areas cover several of the work packages in CINELDI

Some pilot projects are already under way, while others are still in the planning stage, and will be further developed and planned as part of the 2019 work plan. The table below shows all pilot projects that were under way in 2018. Some of the pilot projects were started in 2018, and some pilot projects started in 2017 and were continued in 2018.

Robert Seguin from Hafslund recieved the CINELDI prize 2018 on behalf of the pilot project.



Work packages and priority areas for pilot projects in CINELDI.

Title	Description	Partners
Digital inspection	Extend inspection intervals of substations by utilizing digital solutions.	SINTEF, Hafslund, Eidsiva, Nordlandsnett, Powel, ABB, ...
Demo Stavanger	Examine the possibilities and challenges with new sensors in substations.	SINTEF, Lyse, ABB
New protection concept	Fault localisation in meshed distribution grids using existing protection equipment.	NTNU, Hafslund, ...
Smart cable guard	Test of an online multi-functional monitoring system for MV power cables.	Hafslund, SINTEF
Fault current sensors	Tests of various sensors and indicators for fault localisation.	SINTEF, Hafslund, Skagerak, Eidsiva, ...
Self-healing	Testing and evaluation of a system for automatic fault localisation, isolation and restoration.	SINTEF, ABB, Skagerak, Hafslund

The pilot projects on Fault current sensors and self-healing have been part of the FASaD project but will be continued in CINELDI when FASaD ends in 2018.

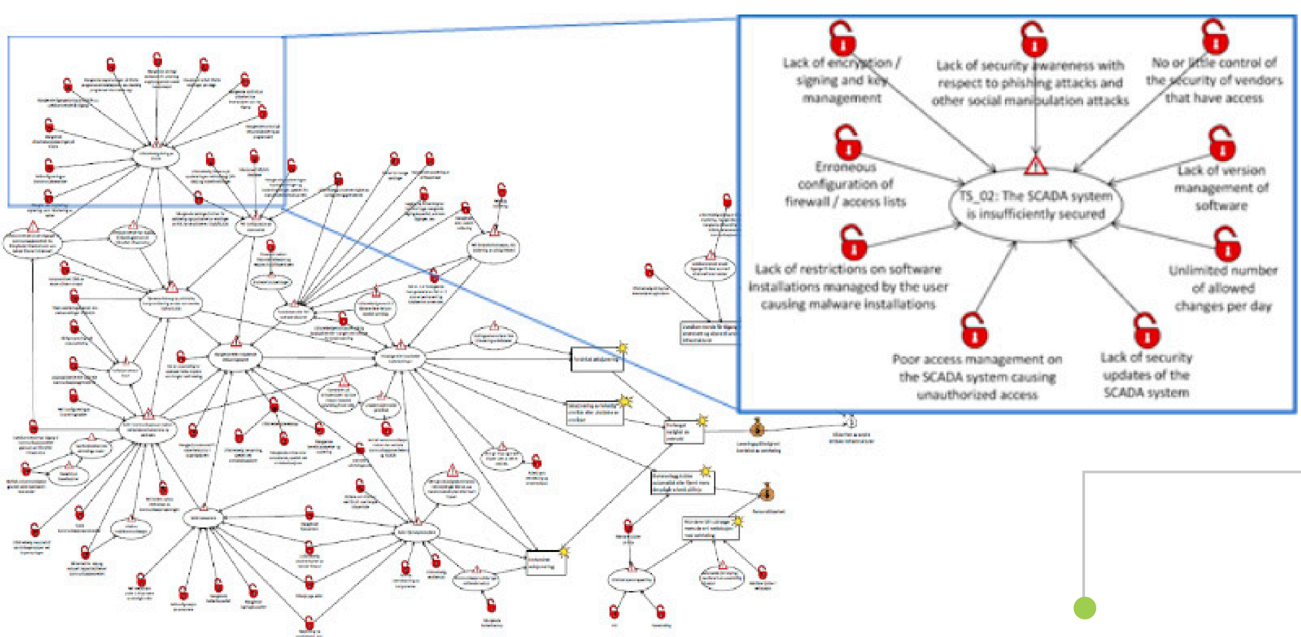
Several pilot projects are also under planning and will be started in 2019. The table below describes pilot projects planned started or assessed in CINELDI in 2019-2020. New ideas will also be assessed continuously.

Title	Description	Partners
Earth fault detection and localisation with AMR data	Development and testing of a system for detecting and locating earth faults by using AMR data.	SINTEF, NTNU, Aidon, Eidsiva, ...
Skagerak Energy lab	Examine possibilities and challenges of large PV-systems and batteries in distribution grids.	SINTEF, NTNU, ABB, Skagerak
Electricity consumption of households	Mapping today's status of electricity consumption for household to increase knowledge about the flexibility potential for different types of customers.	NTNU, SINTEF, ...
Flexibility market	Demonstrated market- based activation of flexibility.	SINTEF, NTNU, Nord Pool, ...
Batteries in the distribution grid	Demonstrated the use of batteries in the distribution grid	SINTEF, Lyse, …
Vatnøy	Test battery/UPS solution as an alternative to upgrade the grid when lack of transfer capability is of relative short duration.	SINTEF, NTNU, BKK…
Utsira	Complex microgrid. Focus in CINELDI will be assessed in 2019.	

SELECTED CASES

#1 RISK IDENTIFICATION AND VISUALISATION OF VULNERABILITIES IN SELF-HEALING GRIDS

CINELDI WP1 "Smart grid development and asset management" develops decision support methodologies and tools for the smart and intelligent distribution grids of the future. New technology provides opportunities for more automation of the distribution grid operation e.g. through automation the process of fault localisation, isolation and restoration (self-healing grid). By using sensors, communication systems, algorithms/logics and remote-controlled switches, reduced consequences of an interruption in form of shorter interruption duration and reduced interruption costs (cost of energy not supplied) can be achieved. At the same time, the complexity and interdependencies between the ICT and power system increases. This may result in new vulnerabilities which in turn can lead to new types of faults, for instance related to cybersecurity.



Identified vulnerabilities (padlock symbol), threat scenarios (circle with danger sign) and unwanted events (square with yellow star) for self-healing grids. To the right is an excerpt of the model; a threat scenario with nine associated vulnerabilities

In a case study conducted in autumn 2018, cybersecurity risks in a self-healing grid have been identified and modelled in the form of a visualised risk model. The model consists of vulnerabilities, threat scenarios and unwanted incidents, and focuses on protection of reliability of supply and safety. The case study targeted a centralized self-healing capability, which is planned to be implemented at a grid company in CINELDI. In the analysis, a team of SINTEF researchers from the fields of cybersecurity and power systems have worked together with the grid company, in order to develop and validate the risk model. The grid company has used detailed context representations of a specific solution to identify risks, while the researchers have analysed cybersecurity of self-healing networks from a conceptual point of view. The outcomes of these two processes were then consolidated, resulting in a complementary risk model. Its strength is an understandable visualization of the complexity and interdependencies of the ICT and power system with respect to cybersecurity. The size and shape of the risk model are shown in the figure to the left together with an example of a threat scenario with associated vulnerabilities.

This example of research shows the usefulness of interdisciplinary collaboration and user involvement in identifying current vulnerabilities and risks. The results will be used further to identify gaps in existing vulnerability frameworks and to close these gaps in terms of cybersecurity. In addition, the results can be used as a basis for e.g. development of recommendations and guidelines in later spin-off projects.

#2 HARDWARE-IN-THE-LOOP TESTING IN THE SMART GRID LABORATORY

CINELDI WP4 "Microgrids" develops an example that can illustrate the benefits of the Power hardware-in-the-loop (HIL) approach. A Phasor Measurement Unit (PMU) -based voltage stability monitoring tool was developed for predicting the voltage collapse. Micro-grids are complex system since they are made with components that are systems *per se* e.g. distributed energy resources (DER), energy storage systems (ES), control and communications systems, etc. The development of tools that can test the integration and operability is fundamental to facilitate the deployment of new technologies or new concepts that can be integrated into our current system in a reliable and safe way. But, how to test new technologies or solutions in microgrids that interact with the distribution grid?

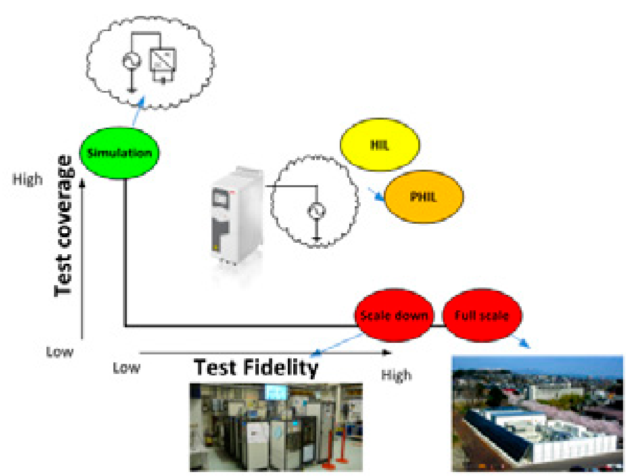


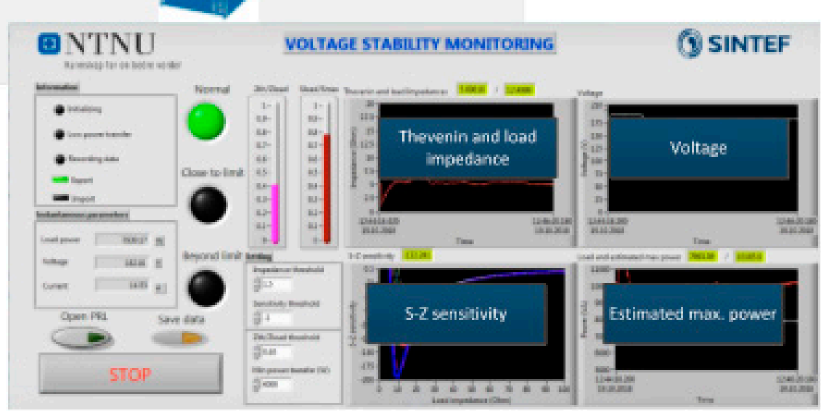
Figure above shows test coverage vs test fidelity for all the different options presented above.

There are basically four options:

- Testing on **full scale** systems, which provides the highest fidelity but with limited test coverage, and high cost.
- **Scaled down version**, a scaled version of the full scale, basically offers the same advantages than full scale with a reduced cost.
- **Offline simulations** are the lowest cost solutions which provides full test coverage but with a limited test fidelity.
- **Hardware-in-the-loop (HIL)** or Power HIL offers a good balance between test coverage and fidelity.

In the smart grid lab, an example was developed that can illustrate the benefits of the Power HIL approach. The setup consists of an emulated distribution grid connected with a 70-kV power converter operated as a constant power load. The power demand in the converter is gradually increased to force a voltage collapse, i.e. following the impedance stability, the converter impedance is greater than grid impedance.

A PMU-based voltage stability monitoring tool was tested for predicting the voltage collapse in system. The tested Power HIL implementation was able to reproduce the virtual distribution grid and the tool was able to monitor the voltage i.e. predict the voltage collapse.



The figure above shows the implementation made in the smart grid lab.

Read three more interesting cases in our digital annual report. Below are snippets from the three cases. The digital annual report can be found at www.cineldi.no -> Annual report 2018

MICROGRIDS: WHAT ARE THEY, VIRTUAL IMPEDANCE AND A CONTROL CONCEPT FOR INVERTERS IN ISLANDED MICROGRIDS

Microgrids are seen as a promising building block for realizing the future, smart, distribution grid (Smart grid), owing to, among other things, its ability for operating connected to the grid or islanded. One of the main challenges with the islanded operation has been proper power sharing between parallel inverters supplying power to the common load.

In this case, the effect of emulating an impedance in the control loop for providing a proper power sharing was considered. This is a technique called virtual impedance. In particular, the modification consisted in considering the transient response of the virtual impedance. The considered test microgrid showed improved damping and power sharing.

ELECTRIC VEHICLES IN NORWAY AND THE POTENTIAL FOR DEMAND RESPONSE

Changing to non-emission transport can result in approximately 1.5 mill. private electric vehicles by 2030, resulting in an energy need of 4 TWh. This represents a 3% increase of the Norwegian electricity consumption. This case presents results from the CINELDI-ModFlex-project, evaluating the consequences of the increasing share of electric vehicles and the potential for demand response and flexibility in charging.

HOW TO ESTIMATE FLEXIBILITY POTENTIAL OF HOUSEHOLD APPLIANCES? (TO REDUCE PEAK LOAD)

In comparison to the traditional grid investments (i.e. installing new lines and components), temporally short-term solutions targeting the peak demand in the network are becoming more economically attractive. Flexibility resources are such solutions which can be used as complementary or alternative to the traditional distribution grid investment practices.

This case describes the data-driven flexibility modelling method that has been developed.

This case describes the data-driven flexibility modelling method that has been developed to estimate the flexibility potential of household appliances to reduce peak loads. It also describes what the specific characteristics of shiftable atomic loads are and how this was considered in the modelling.

Read more on www.cineldi.no -> Annual Report 2018

INTERNATIONAL **COOPERATION**

SCIENTIFIC COMMITTEE (SC)

CINELDI has established an international scientific committee, with the following members in 2018:

- Reader Ivana Kockar, University of Strathclyde, UK
- Director Angel Diaz, Tecnalia, Spain
- Professor Bruce Mork, Michigan Technological University, USA
- Professor Fabrizio Pilo, University of Cagliari, Italy
- Principal Scientist Hannele Holttinen, VTT, Finland
- Associate professor Mattia Marinelli, DTU, Denmark

The purpose of the committee is to give advice to the research in CINELDI, give input to the plans and new research topics, contribute to coordination of the research and laboratory activities between participating institutions and contribute to organisation and coordination of international research applications.

Two meetings have been held with the SC in 2018, where status and plans for the six work packages in CINELDI were presented and discussed. SC gave input to the plans for 2019, and ideas for possible project cooperation and international workshop at the CINELDI-days 2019 were discussed.

INTERNATIONAL COOPERATION IN CINELDI

In WP1, cooperation with University of Cagliari has been initiated regarding a case study in the SPREAD tool on planning of active distribution networks.

In WP3, there is cooperation between guest researcher / professor Robert Bitmead (UC San Diego) and PhD in WP3 (Mohammad Ali Abooshabab), and between professor Steven Gabriel (Maryland University) and Postdoc in CINELDI (Mario Blazquez de Paz).

WP4 is progressing well with international collaboration and have collaboration with Shanghai Jiao Tong (China), Aalborg University (Denmark), IMDEA (Spain), Universidad Tecnica de Pereira (Colombia). WP4 is in the process of developing collaboration with Delhi Technological University and Indian Institute of Technology – Delhi, both in India. WP4 have had visit from two exchange students (PhD) from China and Colombia, within microgrids.

CINELDI has an ongoing cooperation with DTU on integration of EVs as a flexible resource (WP5). This cooperation has resulted in a joint paper between DTU, NTNU and SINTEF Energy Research. There have also been meetings with MIT regarding cooperation within grid planning, optimisation of energy storage, flexibility and EVs.

COOPERATION WITH INTERNATIONAL PROJECTS

CINELDI has established cooperation with several EU projects, both within FP7 (ELECTRA IPR), and H2020 (SmartNet and INVADE). The SmartNet project is strongly related to WP3 in CINELDI, and WP5 collaborates with the INVADE project. CINELDI also collaborates with the ERA-Net projects SmartGuide, MATCH and IHSMAG.

CINELDI has contributed to the H2020 application FlexPlan in response to call H2020/LC-SC3-ES-6-2019 "Research on advanced tools and technological development" and participates in the newly granted PAN-T-ERA, call H2020-SC3-ES-7-2018 "Pan-European Forum for R&I on Smart Grids, Flexibility and Local Energy Networks".

CINELDI works together with EERA (European Energy Research Alliance) JP Smart Grids through participation from SINTEF Energy Research and NTNU, contributing to alignment of research and innovation priorities in Europe within Smart Grids.

WP2 is involved in COST Action (CA15127) Resilient communication services protecting end-user applications from disaster-based failures (RECODIS). This has resulted in joint publications.

WP4 collaborates with the ROME project within microgrids, under the India-Norway R&D program on smart grids.

CINELDI has also contributed to establishing a description of the research program related to transport and Electrical Vehicles for a joint call with MOST in China, under the China-Norway program.

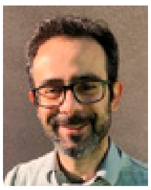
PARTICIPATION IN INTERNATIONAL FORA

Active participation in international standardisation bodies, networks and expert groups is strategically important for influencing the development within Smart Grids through knowledge sharing, innovation and standardisation. CINELDI partners are participating in various international fora:

- IEC TC8, IEC System Committee Smart Energy, and CENELEC TC8X: Kjell Sand is a member of the International Standardisation Committees
- Global Smart Grid Federation: Kjell Sand was board member until April 2018. (The Norwegian Smartgrid Centre is no longer a member of GSGF).
- Mission Innovation: Kjell Sand is a Norwegian representative in the Mission Innovation challenge no 1 - #IC1 on Smart Grids on behalf of the Norwegian Ministry of Petroleum and Energy, the Research Council of Norway and FME CINELDI.
- ETIP SNET: Grete Coldevin is co-chair in the National Stakeholders Coordination Group.
- ISGAN: Hans Terje Ylvisåker is the regular member, while Grete Coldevin is the alternate member of the Executive Committee on behalf of the Norwegian Ministry of Petroleum and Energy.
- EERA JP Smart Grids, SP on Energy Storage: Magnus Korpås is a sub-task leader for Economic evaluation of energy storage.
- EERA JP Energy System Integration: Olav Fosso is NTNUs representative.
- IEEE Innovative Smart Grid Technologies (ISGT) Europe 2018: Gerd Kjølle and Olav Fosso are members of the technical committee.
- CIRED: Gerd Kjølle and Oddbjørn Gjerde are members of the Working Group on Resilience of Distribution Grids.
- CIRED: Dag Eirik Nordgård is a member of the Directing Committee
- CIGRE: Dag Eirik Nordgård is a member of the Study Committee C6 Distribution systems and Dispersed generation.
- CIGRE JWG C6/C2.34 "Flexibility provision": Hanne Sæle and Andrei Morch are members of the working group.
- IEA Task 25 Collaboration on wind and integration and use of flexibility: Magnus Korpås is a member.
- International Workshop on Resilient Networks Design and Modelling", Aug 27-29, 2018: Poul Heegaard was General Chair

RECRUITMENT

OVERVIEW OF RECRUITED PHDS AND POST DOCS WITHIN CINELDI



Michele Garau
Period: 2018-2021
WP: 1 / Position: PostD

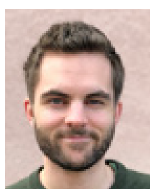
Romina Muka
Period: 2018-2022
WP: 2 / Position: PhD

Fredrik Bakkevig Haugli
Period: 2017-2021
WP: 2 / Position: PhD

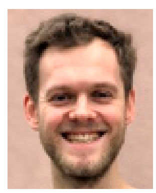
Mohammad Ali Abooshahab
Period: 2017-2020
WP: 3 / Position: PhD

Güray Kara
Period: 2017-2020
WP: 3 / Position: PhD

Kalpanie Mendis
Period: 2018-2022
WP: 4 / Position: PhD



Fredrik Göthner
Period: 2017-2020
WP: 4 / Position: PhD



Kasper Thorvaldsen
Period: 2018-2022
WP: 5 / Position: PhD

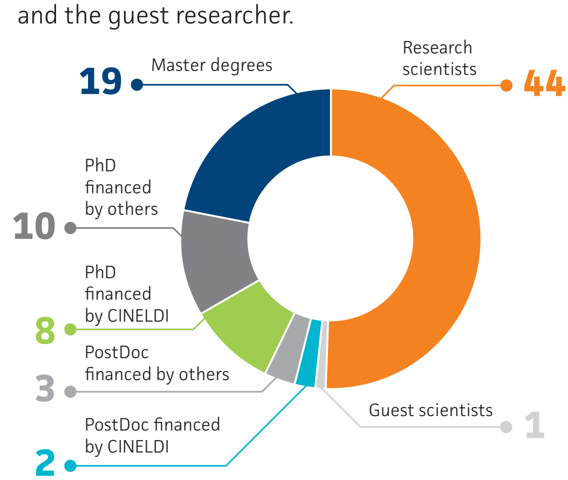
Ingvild Fjellså
Period: 2017-2020
WP: 5 / Position: PhD

Mario Blazquez De Paz
Period: 2017-2019
WP: 3 / Position: PostD

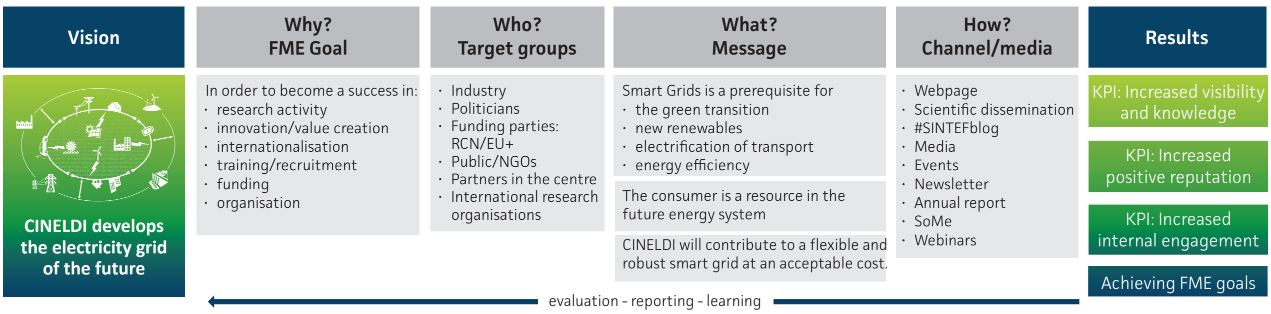
During 2018 some additional PhDs and Post Docs have been recruited, and in total there are now 8 PhDs and 2 PostDocs working at CINELDI during the first research phase. A total overview is presented in the table below

In 2018, 242 persons were involved in CINELDI in total. 44 researchers from SINTEF Energy Research, NTNU and SINTEF Digital participated in the work (including centre management), and 143 representatives from the 27 user partners were involved. Among the students related to NTNU, there were 8 PhDs and 2 PostDocs funded by the CINELDI centre, and 10 PhDs and 3 PostDocs cooperating with CINELDI, with funding from other sources. 1 Guest researcher cooperated with CINELDI in 2018. The number of involved persons for all the categories have increased compared to 2017.

At NTNU, 19 master students concluded their MSc in cooperation with CINELDI in 2018. These students worked on their project theses during the autumn 2017 and delivered their master thesis during 2018. Among the researchers and students, the gender distribution was 72% men vs. 28% women. Among the researchers there were 27% women, and among the master students there were 42% women. The share of women among the PhDs/PostDocs funded by CINELDI is 30% (3 out of 11 in 2018), and there were only men among the PhDs/PostDocs funded by other resources and the guest researcher.



COMMUNICATION



Simplified graphic representation of the FME CINELDI Communication plan.

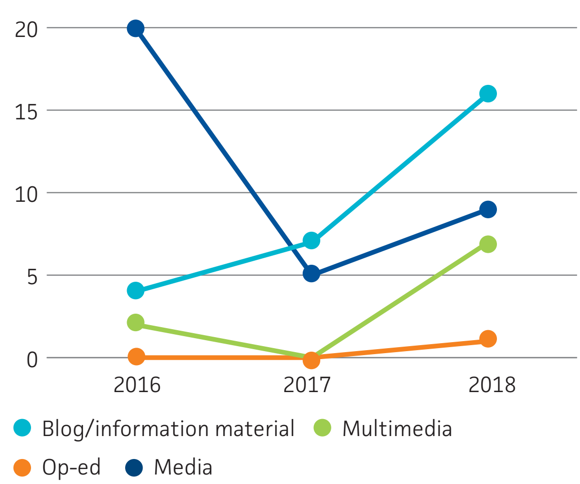
Reaching CINELDI's vision of developing the electricity grid of the future requires both industrial and political willingness as well as public acceptance. Communication is an important tool in reaching the Centre vision. Open and engaging communication of scientific results and Centre activities is therefore a prioritized strategic activity.

External and internal communication shall contribute to CINELDI becoming a successful centre through training, sharing, visibility and dialogue. CINELDI aims to actively communicate innovations, research, knowledge and project results to raise the level of awareness and knowledge about smart grids in the industry, to the public and politicians, and specifically CINELDI specific contributions in this area.

To strengthen CINELDI's communication activities in 2018, the Communication department of SINTEF Energy Research was engaged. Focus areas for the increased communication effort has been quality scientific blogs at #SINTEFBlog, video content and keeping cineldi.no up-to-date.

COMMUNICATION IN NUMBERS

Cristin registrations



As a result of the communication effort, there has been increased visibility and higher communication activity. We did not reach as many media clips as CINELDI's launch year. This is a focus area in 2019.

COMMUNICATION CHANNELS

Web

The CINELDI web-page provides information about the Centre, its research and other activities like events and conferences.

Newsletter

In 2018, 5 newsletters were sent out, mainly to the Consortium.

- December 21, 2018 CINELDI Nyhetsbrev desember 2018
- August, 2018 CINELDI Nyhetsbrev august 2018
- June 29, 2018 CINELDI Nyhetsbrev juni 2018
- April 16, 2018 CINELDI Nyhetsbrev april 2018
- February 7, 2018 CINELDI Nyhetsbrev februar 2018

Twitter

The CINELDI Twitter account (@CINELDI_FME) was created in April 2018. The account is used to share news about Centre activities, popular science publications like videos, posts on #SINTEFBlog and conference news.

The target groups of the Twitter account are consortium members, potential partners, researchers, governments (domestic and international) and the "interested public".

In 2018, CINELDI had:

109 followers

33 400 tweet views

20 tweets

The most popular tweet of 2018 was a video of Centre Director Gerd Kjølle summarizing the CINELDI Days 2018, with 2 400 views.

Media and op-ed

In order to reach a wider audience (outside of the consortium) CINELDI has published op-eds and contributed to media coverage of smart grids. In total, CINELDI had 8 media clips, 1 Op-ed and 7 videos and podcasts in 2018. Here are three examples:

#1 WP 3 leader Hanne Sæle was interviewed on a podcast called "Energibransjens ukeslutt" where she gave her and CINELDI's thoughts on the future of the Norwegian Power market. This podcast is a leading energy podcast in Norway.

#2 Centre Director Gerd Kjølle, together with WP3 leader Hanne Sæle wrote an Op-ed in Dagens Næringsliv called "Folk vil dele på strømmen" *(People want to share their electricity)*, based on CINELDI research showing that in case of an outage, 50% of people are willing to use less electricity to help a neighbour if he/she can get the electricity back faster.

#3 Centre director Gerd Kjølle, together with WP5 leader Magnus Korpås was interviewed about batteries becoming an integrated part of the distribution grid. It was republished by several media outlets. The picture is from *energiteknikk.no*, a website dedicated to energy related news.

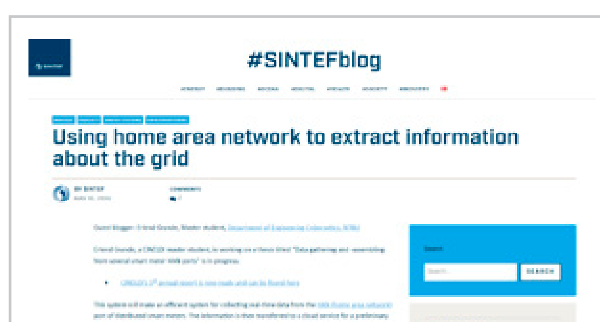
Blogs

CINELDI has contributed several blogs in 2018, all of which has been published on www.blog.sintef.com (#SINTEFBlog). 2018 was a very good year for CINELDI's blog activity.

The top three blogs in 2018 were:

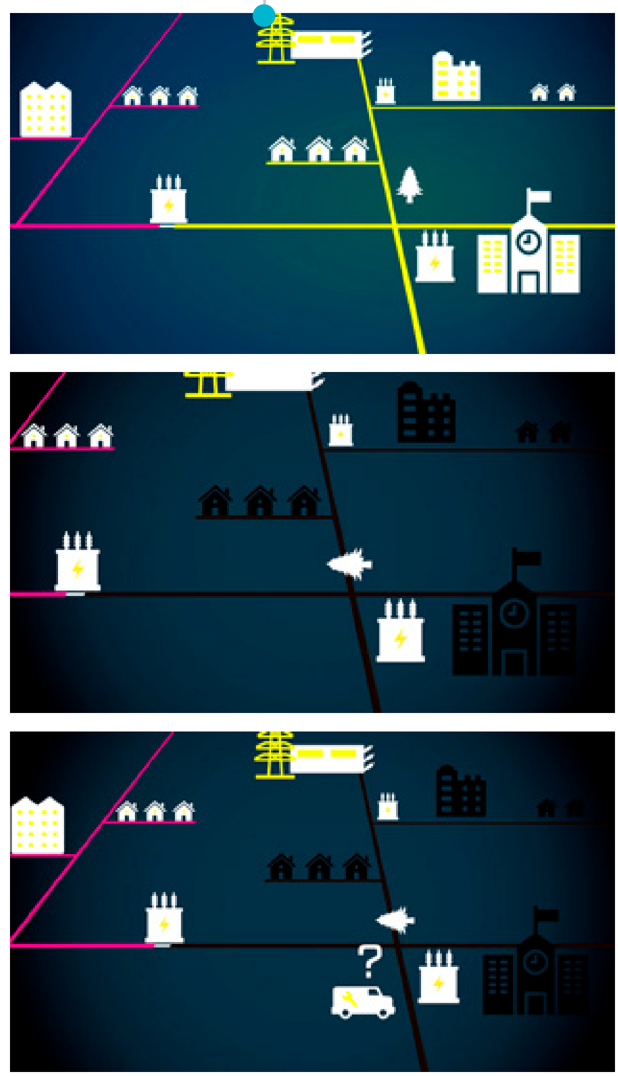
CINELDI partnersamling: planlegging og asset management i fremtidens distribusjnsnett had 219 views.

5G enabling digitalization of the distribution grid had 215 views



Using home area network to extract information about the grid had 199 views.

Anne Steenstrup-Duch, Communication director at SINTEF Energy, held the final key-note for 300 participants at "Smartgridkonferansen 2018", about CINELDI and Smartgrid communication. Smartgridkonferansen is an annual event hosted by Energi Norge and the Norwegian Smartgrid Centre.



Watch our one minute film about self-healing distribution grids – www.cineldi.no -> Annual report 2018

APPENDICES

PERSONNEL

CINELDIs Key Researchers

Name	Institution	Main research area
Synne Garnås	SINTEF Energi AS	Smart grid operation
Oddbjørn Gjerde	SINTEF Energi AS	Smart grid development and asset management
Tonje Skoglund Hermansen	SINTEF Energi AS	Smart grid development and asset management
Maren Istad	SINTEF Energi AS	Smart grid operation
Gerd Hovin Kjølle	SINTEF Energi AS	Smart grid scenarios and transition strategies
Magne Lorentzen Kolstad	SINTEF Energi AS	Microgrids
Jorun Irene Marvik	SINTEF Energi AS	Microgrids
Andrei Z. Morch	SINTEF Energi AS	Smart grid operation
Eivind Solvang	SINTEF Energi AS	Smart grid development and asset management
Iver Bakken Sperstad	SINTEF Energi AS	Flexible resources in the power system
Hanne Sæle	SINTEF Energi AS	Interaction DSO/TSO
Raymundo E. Torres-Olguin	SINTEF Energi AS	Microgrids
Bendik Nybakk Torsæter	SINTEF Energi AS	Microgrids
Hanne Vefsnmo	SINTEF Energi AS	Smart grid development and asset management
Merkebu Zenebe Degefa	SINTEF Energi AS	Interaction DSO/TSO
Tor Arne Folkestad	NTNU Gjøvik, IES	Smart grid operation
Alemayehu Gebremedhin	NTNU Gjøvik, IVB	Smart grid operation
Kjell Sand	NTNU IE, IEL	Smart grid operation
Hossein Farahmand	NTNU IEL	Flexible resources in the power system
Thomas S. Haugan	NTNU IEL	Microgrids
Magnus Korpås	NTNU IEL	Flexible resources in the power system
Ole-Morten Midtgård	NTNU IEL	Microgrids
Kjetil Uhlen	NTNU IEL	Interaction DSO/TSO
Poul Heegaard	NTNU IIK	Smart grid operation
Sule Yildirim-Yayilgan	NTNU IIK	Smart grid operation
Morten Hovd	NTNU ITK	Interaction DSO/TSO
Asgeir Tomasgard	NTNU IØT	Smart grid scenarios and transition strategies
Marianne Ryghaug	NTNU KULT	Flexible resources in the power system
Tomas Moe Skjølsvold	NTNU, KULT	Flexible resources in the power system
Gencer Erdogan	SINTEF Digital	Smart grid development and asset management
Christian Frøystad	SINTEF Digital	Smart grid operation
Sture Holmstrøm	SINTEF Digital	Microgrids
Martin G. Jaatun	SINTEF Digital	Smart grid operation
Geir Mathisen	SINTEF Digital	Smart grid operation
Marie Moe	SINTEF Digital	Smart grid operation

Name	Institution	Main research area
Richard Moore	SINTEF Digital	Smart grid development and asset management
Helene Schulerud	SINTEF Digital	Smart grid development and asset management
Ketil Stølen	SINTEF Digital	Smart grid development and asset management
Kristoffer Gregertsen	SINTEF Digital	Interaction DSO/TSO
Giancarlo Marafioti	SINTEF Digital	Flexible resources in the power system
Bjørn Magnus Mathisen	SINTEF Digital	Smart grid operation
Aida Omerovic	SINTEF Digital	Smart grid development and asset management
Federico Zenith	SINTEF Digital	Microgrids
Borgaonkar Ravishankar	SINTEF Digital	Smart grid operation

Visiting Researchers

Name	Affiliation	Nationality	Sex	Duration	Topic
Robert	Bitmead	USA	M	10.02.2018-12.08.2018	Distributed and hierarchical dynamic state estimation for smart distribution grids

Postdoctoral researchers with financial support from the Centre budget

Name	Nationality	Period	Sex	Topic
Mario Blazquez De Paz	Spain	01.09.2017-31.08.2019	M	Modelling transition strategies towards smart distribution grids
Michele Garau	Italy	11.04.2018-10.04.2022	M	Modelling of Interactions and Interdependencies in Complex Systems of Power Grid and ICT Systems (Postdoc)

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

Name	Nationality	Period	Sex	Topic
Venkatachalam Lakshmanan	India	2017-2019	M	EV and battery flexibility
Jamshid Agahei	Iran	2017-2019	M	EV and battery flexibility
Pedro Crespo del Granado	Spain	2017-2019	M	EV and battery flexibility

PhD students with financial support from the Centre budget

Name	Nationality	Period	Sex	Topic
Mohammad Ali Abooshahab	Iran	25.08.2017-24.08.2020	M	Distributed and hierarchical dynamic state estimation for smart distribution grids
Fredrik T.B.W Göthner	Norway	14.08.2017-13.08.2020	M	Smart power control in microgrids with modern power converters
Ingvild Fjellså	Norway	02.03.2017-06.03.2020	F	Understanding mechanisms and incentives for motivating user flexibility
Güray Kara	Turkey	01.06.2017-31.05.2020	M	Techno-economic optimization for analysing consumer flexibility and related market structures
Fredrik Bakkevig Haugli	Norway	01.09.2017-31.08.2021	M	Distributed and centralized control to support smart grid operation with high quality in a cost-efficient way
Romina Muka	Albania	18.01.2018- 17.01.2022	F	Self-Healing and Autonomous Smart Grid Operation
Kalpanie Mendis	Sri Lanka	08.01.2017-07.01.2022	F	5G for Low-Latency, Secure, and Dependable Communication Services for Fault Handling in Micro Grids
Kasper Thorvaldsen	Norway	01.09.2018-31.08.2022	M	The value of buildings' energy flexibility in the power market

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

Name	Funding	Nationality	Period	Sex	Topic
Mostafa Barani	NTNU	Iran	2018-2021	M	Reliability Studies in Information and Communication Technology (ICT)-dominated Power Systems
Espen Nilsen	Høgskolen Vestlandet	Norway	2016-2020	M	Communication system for demand-response
Tesfaye Amare Zerihun	NTNU	Etiopia	2016-2020	M	Quantitative Modelling of Digital Ecosystems (Case study: smart distribution grid)
Charles Adhra	KPN Prosmart	Ghana	2015-2019	M	A performance modelling approach, architectures and future trends - for protection systems in smart grid transmission networks.
Matthias Hofmann	NFR/Statnett	Germany	2018-2021	M	Demand side flexibility as an alternative to investments in the transmission grid
Sjur Føyen	NTNU	Norway	2018-2021	M	Methods and tools for stability assessment of microgrid systems dominated by Power Electronic converters.
Salman Zaferanlouei	NTNU	Iran	2014-2018	M	Integration of Evs in Smart Grid
Espen Flo Bødal	KPN HYPER	Norway	2016-2020	M	Flexible hydrogen storage (models to be used in WP5)
Dimitri Pinel	FME ZEN	France	2017-2020	M	Investment models for Zero Emission Neighbourhoods
Per Aaslid	Industrial PhD SINTEF Energi	Norway	2018-2021	M	Optimal coordination of distributed energy resources

Master degrees

Name	Sex	Topic
Edem Avevor	M	Smart Grid security in the IoT world
Erlend Grande	M	Data gathering and -assembling from several smart meter HAN ports
Henrik Willett	M	Exploiting the HAN-port for fun and profit
Håkon Edøy Hanssen	M	Data acquisition and analysis of acquired data from geographically distributed sensors connected by 2G / 4G technology.
Marit Tundal	F	Utilizing Blockchain Technology for Settlement in a Microgrid
Anders Holvik	M	Virtual Impedance in ac microgrids
Lene Marie Rognan	F	Optimal coordination/control strategies for multiple energy sources using storage and load flexibility
Mads-Emil Kvammen	M	Signal analysis as a tool for power system identification and optimal control of power systems (Jointly with Føyen)
Ruben Buchmann	M	Harmonic sharing in ac microgrids
Sjur Føyen	M	Signal analysis as a tool for power system identification and optimal control of power systems (Jointly with Kvammen)
Elise Tveita	F	Cost-benefit allocation of flexibility options in distribution systems (2017-2018)
Fredrik Blom	M	A Market-Based Mechanism on Distributed Flexibility Trading (2017-2018)
Ingrid M. Andersen	F	Stochastic optimization of Zero Emission Neighbourhoods in smart cities, utilizing flexible demand, PV and electric vehicles (2017-2018)
Jarand Hole	M	Integrasjon av distribuert fornybar energi I Trøndelag (2017-2018)
Kasper Thorvaldsen	M	Cost-benefit allocation of flexibility options for price arbitrage and capacity provision (2018-2018)
Martin Lillebo	M	Optimal Sizing and Scheduling of Distributed Battery Storage Possibilities in RES Dominated Power System (2017-2018)
Signe Gjørven	F	Integrasjon av sol i det norske kraftsystemet (2017-2018)
Sondre Harbo	M	Agent Based Modelling and Simulation of Plug-in Electric Vehicles
Thea Øverlie	F	Fleksibelt forbruk som en ressurs i fremtidens kraftsystem

STATEMENT OF ACCOUNTS

Funding (kNOK)

	Funding	In-kind	Sum
The Research Council	26 610,3		26 610,3
The Host Institution (SINTEF Energi AS)		3 179,2	3 179,2
Research Partners			
NTNU		4 173,9	4 173,9
SINTEF Digital		1 529,1	1 529,1
Enterprise partners			
Distribution System Operator	925,6	4 476,7	5 402,28
Transmission System Operator & Market Operator	94,6	230,7	325,25
Vendors	74,3	2 957,7	3 032,02
Member organisations	27,0	188,6	215,7
Public partners			
Authorities	300,0	208,2	508,2
Sum			44 976
Costs			
The Host Institution (SINTEF Energi AS)			18 212,8
Research Partners			18 701,0
Enterprise partners			7 853,7
Public partners			208,2
Equipment			0
Sum			44 976

CINELDI PUBLICATIONS REGISTERED IN CRISTIN (CURRENT RESEARCH INFORMATION SYSTEM IN NORWAY)

Peer reviewed Journal publications

Search criteria:

From: 2018 *sub-category:* Academic article *sub-category:* Academic literature review *sub-category:* Short communication
All publishing channels

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

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

Zepter, Jan Martin Wilhelm; Lüth, Alexandra Rebecca; Crespo del Granado, Pedro; Egging, Ruud.
Prosumer integration in wholesale electricity markets: Synergies of peer-to-peer trade and residential storage. *Energy and Buildings* 2018 ;Volum 184. s. 163-176
NTNU

Adrah, C. M.; Yellajosula, J. K.; Kure; Palma, D.; Heegaard, P.E.
An IP Multicast Framework for Routable Sample Value Communication in Transmission Grids, Journal of Communications (ISSN: 1796-2021 (Online); 2374-4367 (Print)*

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*

Peer-reviewed papers

Search criteria:

sub-category: Academic chapter/article/Conference paper *All publishing channels*

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

*These are not yet registered in Cristin with CINELDI project code.

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

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 IEEE International Conference on Environment and Electrical Engineering and 2018 IEEE Industrial and Commercial Power Systems Europe - EEEIC/I&CPS Europe*. IEEE International Conference on Smart Grid Communications (SmartGridComm) 2018 ISBN 978-1-5386-5186-5.
ENERGISINT NTNU

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

Reports

(not registered in Cristin)

Sondre Harbo.
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.
MSc thesis NTNU 2018

Fredrik Blom.
A Feasibility Study of Blockchain Technology As Local Energy Market Infrastructure.
MSc thesis NTNU 2018

Sjur Føyen, Mads-Emil Kvammen.
A signal analysis toolbox for power system identification in Smart Grids.
MSc thesis NTNU 2018

Håkon Edøy Hanssen.
Data acquisition and analysis of acquired data from geographically distributed sensors connected by 2G / 4G technology.
MSc thesis NTNU 2018

Erlend Grande.
Data gathering and -assembling from several smart meter HAN ports.
MSc thesis NTNU 2018

Thea Øverlie.
Forbrukerfleksibilitet som en ressurs i fremtidens kraftsystem.
MSc thesis NTNU 2018

Ruben Buchmann.
Harmonic Sharing in Microgrid Applications - Modeling, Developing and Evaluating a Microgrid Control System With Harmonic Sharing Capability.
MSc thesis NTNU 2018

Martin Lillebo.
Impact of EV Integration and Fast Chargers in a Norwegian LV Grid - An analysis based on data from a residential grid in Steinkjer.
MSc thesis NTNU 2018

Jarand Hole.
Integrasjon av distribuert fornybar energi i Trøndelag.
MSc thesis NTNU 2018

Signe Gjørven.
Integrasjon av sol i det norske kraftsystemet.
MSc thesis NTNU 2018

Elise Tveita.
Methods for Cost Allocation Among Prosumers and Consumers Using Cooperative Game Theory.
MSc thesis NTNU 2018

Kasper Thorvaldsen.
Multi-Market Optimization of Energy Storage Taking Into Account Uncertainty.
MSc thesis NTNU 2018

Lene Marie Rognan.
Photovoltaic Power Prediction and Control Strategies of the Local Storage Unit at Campus Evenstad.
MSc thesis NTNU 2018

Henrik Willett.
Security evaluation of communication interfaces on smart meters.
MSc thesis NTNU 2018

Edem Avevor.
Smart Grid security in the IoT world.
MSc thesis NTNU 2018

Ingrid Andersen.
Stochastic Optimization of Zero Emission Buildings.
MSc thesis NTNU 2018

Marit Tundal.
Utilizing Blockchain Technology for Settlement in a Microgrid.
MSc thesis NTNU 2018

Anders Holvik.
Virtual Impedance Techniques for Power Sharing Control in AC Islanded Microgrids.
MSc thesis NTNU 2018

Presentations

Search criteria:

Main category: Conference lecture and academic presentation *All publishing channels*

Fjellså, Ingvild Firman.
Det fleksible mennesket 2.0: om sosiale relasjoner i det digitale elektrisitetssystemet. Sosiologisk Vinterseminar; 2018-02-02 - 2018-02-04
NTNU

Fjellså, Ingvild Firman.
Energy practices, reflections and flexibility: Stories from end-users. CenSES Scientific Conference; 2018-11-22 - 2018-11-22
NTNU

Fjellså, Ingvild Firman.
Understand mechanisms and incentives for motivating user flexibility- a PhD prosjekt. Demand Side Management: Empowering the end user in the energy transition; 2018-04-16 - 2018-04-16
NTNU

Føyen, Sjur; Kvammen, Mads-Emil B.; Fosso, Olav B.
Prony's method as a tool for power system identification in Smart Grids. 24th IEEE International Symposium on Power Electronics, Electrical Drives, Automation and Motion - SPEEDAM 2018; 2018-06-20 - 2018-06-22
NTNU

Jaatun, Martin Gilje.
Incident Response & Business Continuity in the Grid. 5th Cyber & SCADA Security for Power and Utilities Industry 2018; 2018-09-26 - 2018-09-28
SINTEF

Korpås, Magnus.
Small-scale vs large-scale flexibility options in high-RES power systems. The MIT Energy Initiative Electric Power Systems Center Fall Workshop; 2018-11-14 - 2018-11-14
NTNU

Steenstrup-Duch, Anne.
SmartGrid konferansen 2018 - kommunisere SmartGrid i CINELDI. Konferanse; 2018-09-12
ENERGISINT

Sæle, Hanne.
Research on the future intelligent, flexible and robust distribution grid –with special focus on potential for demand response from household customers. Demand Side Management: Empowering the end user in the energy transition - IEA DSM; 2018-04-16 - 2018-04-16
ENERGISINT

There might be some discrepancies between the numbers in figure and numbers registered in Cristin, mainly due to FME partners that do not have a university or research institute affiliation or because the FME projectcode has not yet been registered in the post.

Op-eds

Search criteria:

sub-category: Feature article *sub-category:* Editorial *All publishing channels*

Sæle, Hanne; Kjølle, Gerd Hovin.
Folk vil dele på strømmen. *Dagens næringsliv* 2018
ENERGISINT

Media contributions

Search criteria:

Main category: Media contribution *sub-category:* Popular scientific article *sub-category:* Interview Journal *sub-category:* Article in business/trade/industry journal *sub-category:* Sound material *All publishing channels*

Kjølle, Gerd Hovin.
Gir «digitalisering» av nettet innhold. KS Bedrift [Internet] 2018-02-15
ENERGISINT

Kjølle, Gerd Hovin; Korpås, Magnus.
Batterier blir en del av strømnettet. Energiteknikk [Business/trade/industry journal] 2018-06-25
ENERGISINT NTNU

Kjølle, Gerd Hovin; Korpås, Magnus.
Batterier kan bli en del av strømnettet ved høyt strømforbruk. Itbaktuelt [Business/trade/industry journal] 2018-07-25
ENERGISINT NTNU

Kjølle, Gerd Hovin; Sæle, Hanne.
Folk vil dele på strømmen. Gemini [Business/trade/industry journal] 2018-09-23
ENERGISINT

Kjølle, Gerd Hovin; Sæle, Hanne.
Folk vil dele på strømmen - KS bedrift. www.ksbedrift.no [Internet] 2018-09-28
ENERGISINT

Korpås, Magnus.
Slik kan batterier brukes i det norske strømnettet - energiteknikk. Energiteknikk [Business/trade/industry journal] 2018-08-31
NTNU

Olsen, Claude R.; Korpås, Magnus; Kjølle, Gerd Hovin.
Batterier blir en del av strømnettet. gemini.no [Business/trade/industry journal] 2018-06-25
NTNU

Sæle, Hanne.
En digital dugnadsånd med strømdeling kan redusere milliardutbygginger i strømnettet. enerWE [Internet] 2018-10-24
ENERGISINT

Sæle, Hanne.
PODCAST: ENERGIBRANSJENS UKESLUTT – Dette spår ekspertene om Norges strømmarked. enerWE [Radio] 2018-10-26
ENERGISINT

Blogs and information material

Search criteria:

Main category: Information material(s) *All publishing channels*

Hermansen, Tonje Skoglund.
CINELDI partnersamling: planlegging og asset management i fremtidens distribusjonsnett.
ENERGISINT

Hermansen, Tonje Skoglund.
CINELDI-dagene 2018 var en suksess.
ENERGISINT

Hermansen, Tonje Skoglund.
CINELDI-prisen delt ut til et «nytt vernkonsept» – et pilotprosjekt av Hafslund nett.
ENERGISINT

Hermansen, Tonje Skoglund.
Digitizing grid data for a future-proof SmartGrid.
ENERGISINT

Istad, Maren Kristine.
Smartere og sikker nettdrift – hvordan skal vi få til dette?.
ENERGISINT

Kjølle, Gerd Hovin.
CINELDI Annual Report 2017.
ENERGISINT

Kjølle, Gerd Hovin.
CINELDI pilot projects, PhDs, deliverables and milestones are well under way.
ENERGISINT

Kjølle, Gerd Hovin.
Hafslund Nett – Månedens brukerpartner i CINELDI.
ENERGISINT

Korpås, Magnus.
Batterier blir en del av strømnettet.
NTNU

Korpås, Magnus.
Energy Modelling workshop and 5th Pyomofest.
NTNU

Mathisen, Geir.
Using home area network to extract information about the grid.
NTNU

Mendis, Handunneththi V. Kalpanie.
5G enabling digitalization of the distribution grid.
NTNU

Moore, Richard.
Drones protecting the grid – UAS Norway Fagdag.
SINTEF

Sæle, Hanne.
CINELDI WP3 og 5 hadde felles workshop 12. juni.
ENERGISINT

Torsæter, Bendik Nybakk.
Workshop i CINELDI WP4: Mikronett i fremtidens distribusjonsnett.
ENERGISINT

Vefsnmo, Hanne.
CINELDI partnermøte: Utvikle scenarier for fremtidens distribusjonsnett.
ENERGISINT

Multimedia products

Search criteria:

sub-category: Multimedia product *All publishing channels*

Kjølle, Gerd Hovin.
CINELDI Prisen 2018 går til Hafslund Nett for "Nytt vern konsept". SINTEF Energi 2018
ENERGISINT

Kjølle, Gerd Hovin.
CINELDI-dagene ble en suksess. SINTEF Energi Facebook 2018
ENERGISINT

Kjølle, Gerd Hovin.
CINELDI-senterleder svært fornøyd med CINELDI dagene 2018. SINTEF Energi 2018
ENERGISINT

Kjølle, Gerd Hovin.
GREETINGS FROM CINELDI CENTRE DIRECTOR GERD KJØLLE. SINTEF Energi Facebook 2018
ENERGISINT

Kjølle, Gerd Hovin.
Hva får Lyse ut av å være med i CINELDI?. SINTEF Energi 2018
ENERGISINT

Kjølle, Gerd Hovin.
Hvordan bidrar og deltar Skagerak Nett i CINELDI?. SINTEF Energi 2018
ENERGISINT

Kjølle, Gerd Hovin.
Hvorfor er Skagerak Nett med i CINELDI ?. SINTEF Energi 2018
ENERGISINT

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Design og trykk: www.fagtrykk.no Miljømerket trykkeri, lisensnr. 2041 0811

CINELDI – Centre for intelligent electricity distribution
CINELDI is a Centre for Environment-friendly Energy Research (FME).
The objective of the FME-scheme is to establish time-limited research centres which conduct concentrated, focused and long-term research of high international calibre.

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