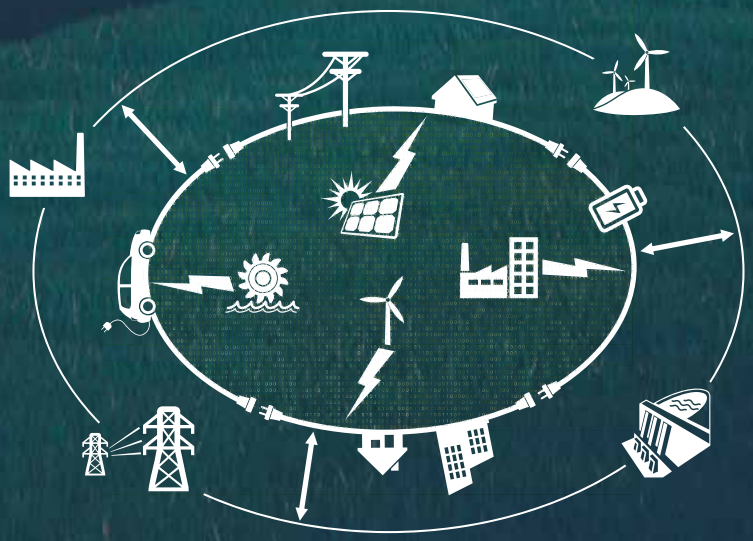
CINELDI

Centre for intelligent electricity distribution

Annual Report 2017



Vision

The CINELDI centre will ensure that we are building the smart energy system of the future.

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

The future grid anno 2030-2040 will be a complex system-of-systems, incorporating various intelligent devices for sensing, controlling, and decision-making. Major new security requirements must be addressed and technologies need to be incorporated that enable customers to make informed choices about their energy use. CINELDI targets innovation on the system level of the future cyber-physical distribution system.

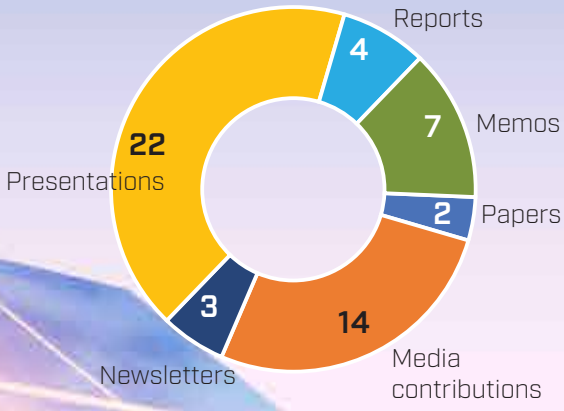
A national team is being built for the long-term research needed to digitalise the distribution system, where multidisciplinary research teams at SINTEF and NTNU work together with leading grid companies (DSOs), the system operator (TSO), market operator, and leading technology providers, Authorities and member organsations. CINELDI has the capacity to act as a national hub for long-term research and innovation as well as being an international reference project.

29 partners

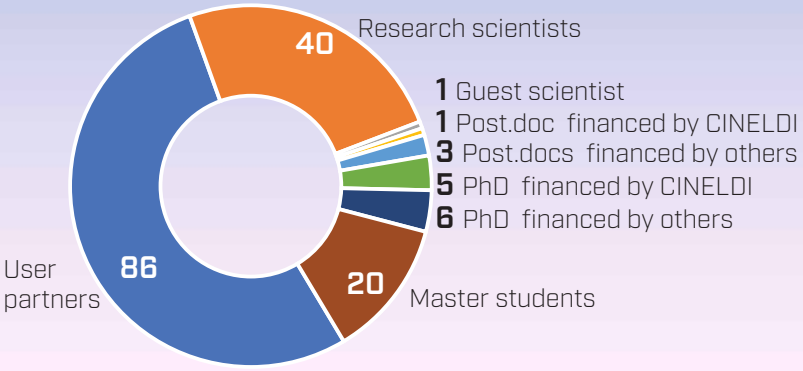
8 years

40 million

Publications



Personnel



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Gerd Kjølle is the Centre Director of CINELDI.

Dr. Kjølle is Chief Scientist at the Energy Systems Department, SINTEF Energy Research. She is also an Adjunct Professor at the Norwegian University of Science and Technology (NTNU), Department of Electric Power Engineering.

Gerd has more than 30 years of R&D experience from the electric power sector. She has collaborated with grid companies, transmission system operators, electric power industry and authorities through bilateral- and innovation projects, including multi-disciplinary projects and EU-projects. Her focus areas include energy systems planning, power system analyses, risk and vulnerability analyses, reliability and interruption cost assessment, and smart grids.

Gerd Kjølle holds a PhD in Electric Power Engineering from NTNU in 1996.

Message from the Director

The Centre for Intelligent Electricity Distribution, CINELDI, is well established, and 2017 was the first year of operation. CINELDI will work towards digitalising and modernising the electricity distribution grid for higher efficiency, flexibility and robustness. The research partners and user partners have made joint efforts to get the work started. Thanks to all partners for the contributions in CINELDI in 2017!

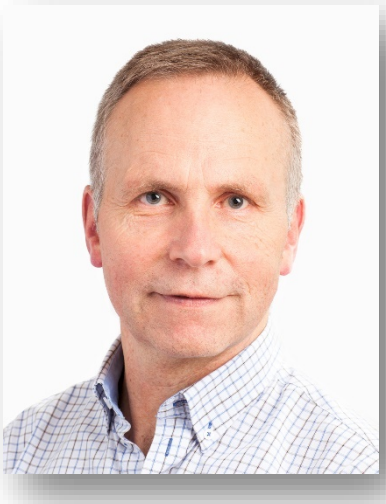
Workshops have been arranged discussing the main challenges and opportunities in different research areas and which tasks to take on in the first phase of research in CINELDI. This has been supported by literature reviews, surveys and studies of current practices.

Important results in 2017 were identification of driving forces for system innovation. This was the basis for the development of many mini scenarios which will further be developed into main scenarios for the electricity grid of the future.

In 2017, several PhDs and Postdocs are recruited and all planned research tasks are in progress. A few pilot projects are started, in the Norwegian Smart Grid laboratory as well as in living labs, i.e., in the real grid. More pilot projects are in the starting line.

You can read all about this and some highlights from the results in the first Annual Report.

Good reading!



Sigurd Kvistad is currently Head of Division Operational Control at Hafslund Nett.

He 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.

In later years, he has been heavily involved in Smart Grids, as the leader of the Digitalisation Program at Hafslund Nett and as project manager for Smart Metering (AMS).

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

Greetings from the Chairman of the Board

The electricity system is undergoing major changes. Society wants a future clean from CO_2 emissions. Hence, more and more sectors are electrified and electricity produced from intermittent, unregulated and distributed sources such as solar and wind is integrated.

The technology is developing rapidly, with new sensors, microgrids, energy storage and advanced control systems becoming available, while new buildings are more energy efficient. Due to such changes, new business models and eco systems will emerge in the coming years. At the same time, the grid companies have huge reinvestment plans for renewal of the grid and to improve the quality of supply.

This imposes uncertainty and at the same time gives possibilities for all stakeholders in the future smart energy system where the electricity grid will play a major role. CINELDI will help the actors in dealing with the uncertainties and utilise the possibilities for how the grid should be developed and operated, and how flexible consumption and electricity production can be useful resources for a cost-efficient and robust electricity grid.

CINELDI brings together many innovative actors from grid companies (DSOs, TSO), market places, technology providers, member organisations and authorities, with prominent research institutes, to contribute to the development of solutions for the future.

2017 was the start-up year in CINELDI, providing the foundation for the further work. The board is looking forward to new results in the years to come!

Introduction

The world is changing; Electricity consumption is increasing in all corners of the world and we are facing an energy and climate crisis. There isn't a single big solution to this problem, but one part of the solution is upgrading the electricity distribution grid. Today's distribution grid is ageing, and was not designed to handle the vast amount of electricity generated by solar and wind sources. The needs and sustainability targets of the future energy system cannot be met without upgrading our electricity distribution systems.

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. The knowledge and experience gained will help grid companies, system operators, manufacturers and ICT companies to develop and integrate new technologies and work processes, stimulating innovations.

Vision and Goals

Vision

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The future grid anno 2030-2040 will be a complex system-of-systems, incorporating various intelligent devices for sensing, controlling, and decision-making. Major new security requirements must be addressed and technologies need to be incorporated that enable customers to make informed choices about their energy use. CINELDI targets innovation on the system level of the future cyber-physical distribution system.

A national team is being built for the long-term research needed to digitalise the distribution system, where multidisciplinary research teams at SINTEF and NTNU work together with leading grid companies (DSOs), the system operator (TSO), market operator and leading technology providers. CINELDI has the capacity to act as a national hub for long-term research and innovation as well as being an international reference project.

Goals

The overall objective of CINELDI is to enable a cost-efficient realisation of the future flexible and robust electricity distribution grid.

This will pave the ground for increased distributed generation from renewable resources, electrification of transport, and more efficient power and energy use. The objective is to tailor the grid for use by smart grid customers, electric vehicles, solar power facilities and other renewable electric power.

Secondary objectives:

- 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 utilize this flexibility.
- Microgrid concepts, technologies and solutions for optimal design, operation, and integration with the distribution system.
- Recommendations for the transition to the electricity distribution system of 2030-2040.
- Ease deployment of research results by extensive use of small-scale pilots and test.
- Ensure efficient knowledge transfer through user-involvement.

The CINELDI centre will develop a knowledge base for grid owners and the public authorities to improve efficiency, reduce operational and investment costs and promote future-oriented development and regulation of the power grid. The centre will also develop a roadmap for the transition to smart electricity distribution grids in Norway.

The centre will promote the development of new market opportunities for technology providers in the form of new products, services and solutions, seeking to strengthen the competitiveness of suppliers in the international arena.

CINELDI gives priority to training researchers and Master's degree students in Smartgrid applications, and the transfer of expertise to industrial actors. About 20 PhD and Postdocs will be recruited. CINELDI also targets about 150 Master projects.

Innovation objectives:

Innovations from CINELDI shall reduce total distribution system costs compared to the "business as usual"-solutions, and leverage business opportunities for technology providers in the national and international markets. There is a significant potential for cost reductions by applying new innovative solutions. An illustration is given for a reduction of 10 % (which is moderate), amounting to cost savings close to 2 billion NOK/year. A part of these cost reductions comes from reducing power system losses and from more cost-efficient integration of renewables and electrical vehicles. CINELDI will have an active role in standardisation which is a key element in the realisation of the Smart Grid. Good standards will reduce stakeholder costs and the technological risk related to developing new products.

Objectives:

- Facilitate the deployment of successful research results based on small-scale pilots and testing in dialogue with the Coordination Forum for National Smart Grid Demos.
- Ensure efficient transfer of knowledge between researchers and user partners through in-house tailor-made seminars, promotion of mobility between research community and industry, encouraging industry participation in the supervision of MSc- and PhD-students
- Initiate and keep track of the transfer of innovative ideas from research to user partners
- Establish a contact point towards Small and Medium-sized Enterprises and other relevant industrial partners.

International objectives:

- CINELDI has the ambition to establish itself as an international reference project on distribution grids for the future.
- CINELDI consortium partners will continue their active participation in international expert groups, networks and standardization bodies, including CIGRE, CIRED, ISGAN, GSGF, IEC, and CENELEC. These bodies are important for knowledge sharing, standardisation and innovation in the Smart Grid area.
- CINELDI partners will continue and strengthen their participation in the technology platform ETIP SNET and the research alliance EERA JP Smartgrids. This participation will promote CINELDI and consortium partners as attractive participants in EU H2020 projects.

Research Plan and Strategy

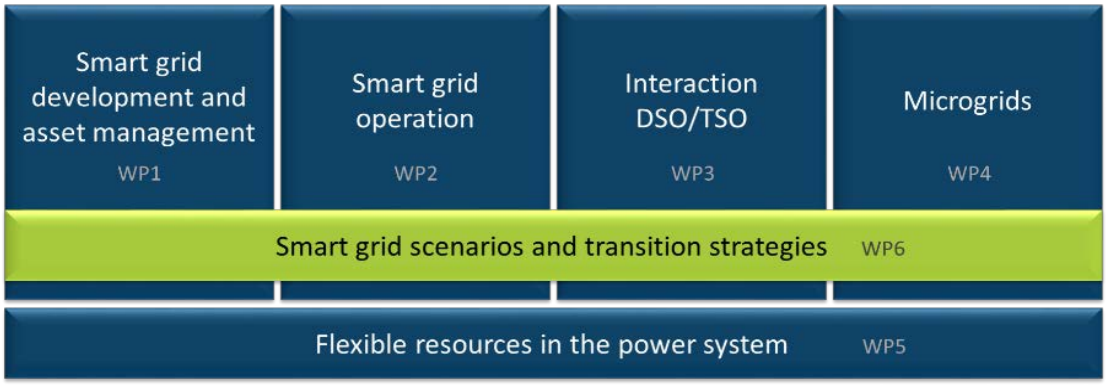
Research Plan

The research in CINELDI targets the situation in 2040, i.e., twenty years after deployment of the first-generation smart meters (AMI) by 2019 in Norway. The research tasks are designed to meet the objective of the FME in close cooperation between the four technologies power engineering, cybernetics, information and communication technology with support from social sciences.

The research activities are organised in six work packages.

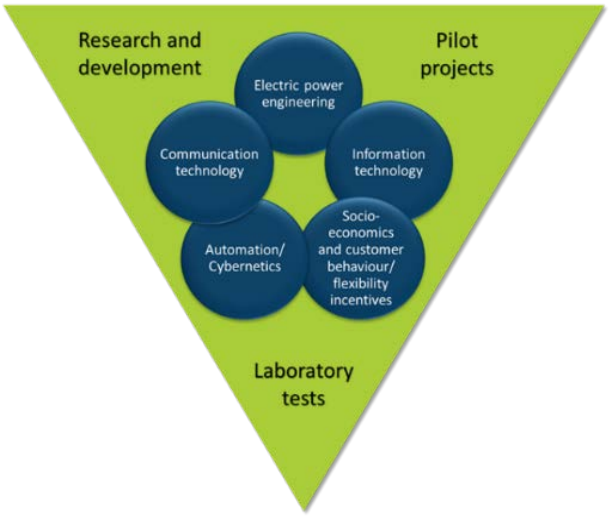
- Smart grid development and asset management (WP1)
- Smart grid operation (WP2)
- Interaction DSO/TSO (WP3)
- Microgrids (WP4)
- Flexible resources in the power system (WP5)
- Smart grid scenarios and transition strategies (WP6)

In addition, there is an activity on coordinating pilot projects in different work packages of CINELDI.



Work package structure of CINELDI

The organisation of research tasks in CINELDI reflects the main aspect of power system operation and management. This ensures that each work package (WP) addresses research questions of high relevance for both industry and society, and enables the academic partners to work in close collaboration, regardless of discipline. Moreover, it facilitates interaction and communication between research and industry partners, thus fostering innovation and value creation. The WPs are tightly integrated to stimulate the innovative ability of consortium partners at the electricity distribution system level. The design of work packages, the application of Use Case Methodology (UCM), and active use of research infrastructure including the Norwegian Smart Grid Laboratory, pilots and living labs at user partners. This forms a platform that will enable and stimulate efficient multidisciplinary research, development and value creation.



Multidisciplinary research within CINELDI

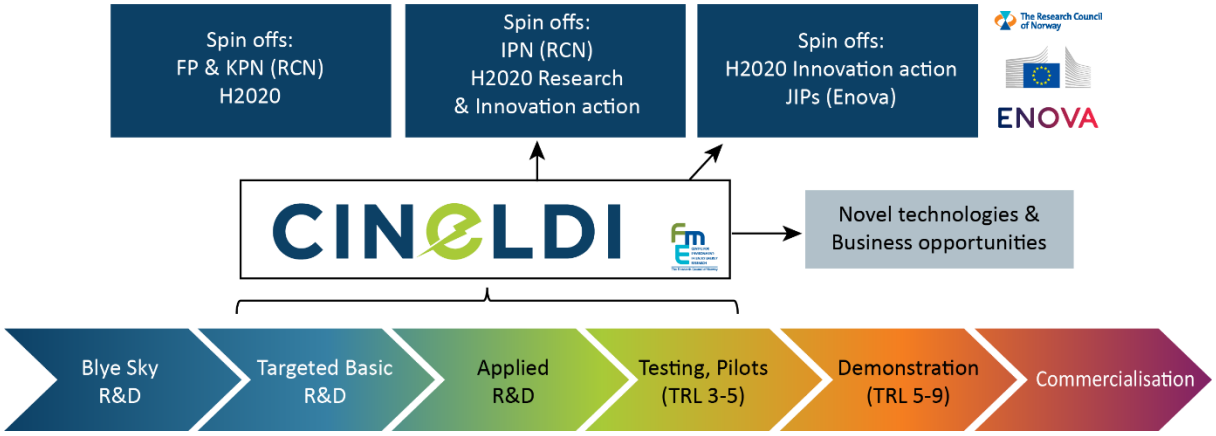
Simulations, labs and pilots constitute arenas for testing and demonstration of innovations and prototypes, and for collecting and analysing data for developing new methods, models, tools and solutions.

Innovation Strategy

CINELDI is positioned in the research driven innovation chain between basic research and pilot/testing facilitation at lower Technology Readiness Levels (TRL).

Emphasis in CINELDI is put on advanced basic and applied research, which provides in-depth knowledge, methods, and tools that will be tested in laboratories; simulated environments and small-scale field pilots guiding industry in what might be viable functions and solutions for the intelligent distribution system of the future.

CINELDI's ambition is to build up capacity and succeed in "spin-off" ideas and partnerships for new national and international projects along the whole value chain, and particularly, to succeed in H2020 projects with higher TRL levels (5-8).



Spin Offs projects from FME CINELDI in the R&D-D innovation chain

The innovation strategy will contribute to closing the gap between targeted basic research, applied R&D, and Testing/pilot (TRL 3-5) on the one hand, and Demonstration (TRL 5-9) and novel business and technology opportunities on the other hand. The R&D activities in CINELDI shall result in "spin-offs" in the form of IPN projects for the Research Council of Norway, National demonstration projects for Enova, and International H2020 Innovation action projects (TRL 5-9).

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 and
- a Scientific Committee (SC).

The research activities are organised into six work packages (WPs):

- Smart grid development and asset management (WP1)
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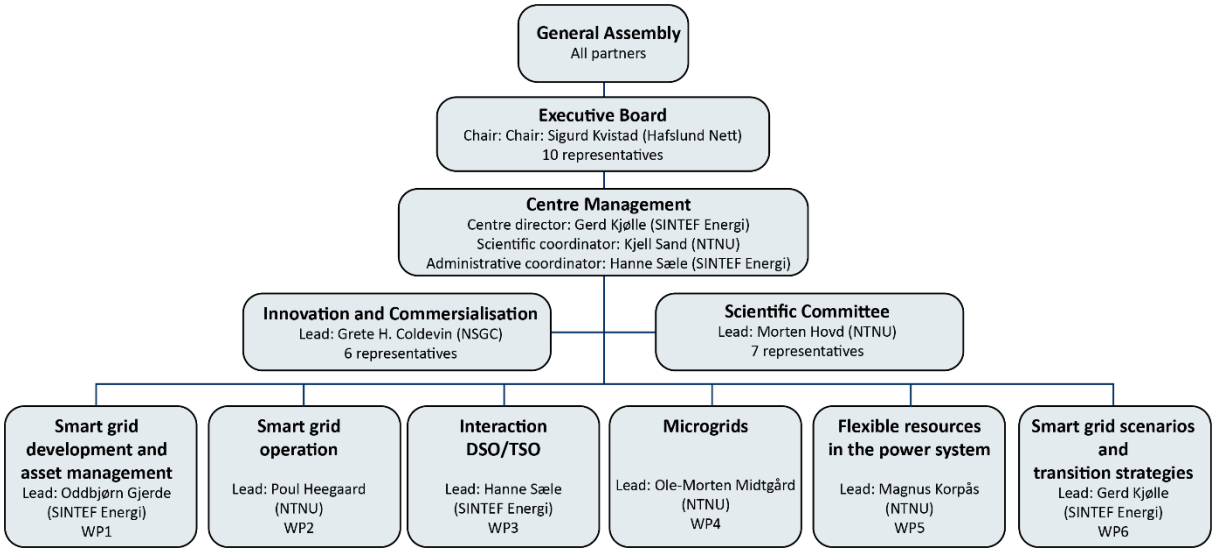
- Smart grid scenarios and transition strategies (WP6)



Outline of governance structure for CINELDI per 2017

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

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 is an industry-led centre in the start-up phase, so in the first period there has been a large focus on establishing arenas for involving user partners. This has been performed through several workshops within the different work packages in CINELDI, also related to the discussion of pilot projects.

CINELDI has a total of 29 partners, including 26 user partners. In 2017, partners have participated in several workshops, to discuss activities and contribute to the research in CINELDI.

WP6 focuses on scenarios and transition strategies for the future electricity distribution grid. In May 2017, a workshop was held with all partners, where the topic was to describe drivers, barriers and possible system innovation. This has been the basis for the development of mini scenarios, at a workshop in October.

June 22nd a workshop was organised in collaboration between WP1 and WP2, including group work, while WP3, 4 and 5 organised a workshop on September 7th. Here, presentations were given by some user partners, related to each of the work packages before group work was carried out for each WP. The results of the group work have provided useful input for further work in the various WPs.

The largest collection of user partners was on the CINELDI days, which were held October 31rd - November 1st. The aim of these days was to gain an overview of the status of the academic work and plans, partly to strengthen user involvement and interaction in the consortium, and to create a common understanding of opportunities for spin-offs and EU projects.

Furthermore, work processes and information flow in the project were evaluated through the users' question time. Group work was also undertaken to plan / develop pilot projects in CINELDI within various areas of major importance for the future distribution network.

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 work packages are all well started by 2017. 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 9 PhD students and 2 post-doctoral researchers integrated in the work packages, as well as many master projects.

Some highlights from the research in 2017 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.

Today's practice in the DSOs

In 2017 a questionnaire was sent to the DSOs to assess today's practice regarding grid planning methodologies. The results show that different implementations in Excel, as well as Powel's Netbas are the most common tools used for analyses for grid planning purposes. The DSOs wish to consider new aspects such as prosumers, end user flexibility, distributed storage and variable generation (PV, wind) in their planning, but lack good tools. Uncertainties are only to a limited extent accounted for. Many of the DSOs indicate that the main reason why more analyses are not carried out as part of the grid planning process, is that they do not have sufficient high-quality input data. It was found that part of the data is still stored on paper at 67% of the respondents (9 DSOs in total). They are in the process of digitizing this data.

Planning methodologies needs and gaps

A partner workshop was arranged in June to discuss state of the art of planning methodologies from the DSO perspective. The partners were invited to give input on what they wanted WP1 to focus on. The input from the partners were sorted in three levels; driving forces that influence on the future grid planning; challenges that need to be solved in the future planning methodology; and how to solve the challenges / requirements to the methodology.

In October, the research partners arranged a meeting with Fabrizio Pilo, professor at the University of Cagliari (Italy), and convener of the CIGRÉ WG C6.19 *Planning and optimization methods for active distribution systems*. The planned research activities in CINELDI WP1 were discussed, and aligned with the research needs from the CIGRÉ working group.

Output from the workshops and other discussions, the results of the questionnaire, together with a literature study on future planning methodology are used as input to describe the needs and gaps related to planning methodology for the future distribution system. This description is still ongoing work.

Automatic inspection for condition monitoring

Further, work has been carried out regarding "Next generation asset management", to provide methods and tools to support risk-based asset management in the future active distribution system. New sensors, increased sensor coverage, online condition data acquisition and analysis, data management and big data analytics will provide new possibilities, regarding efficient and more precise assessment of technical condition. Use of digital photos requires unstructured data (photo/video) analysis.

So far work has focused on how to establish information of the technical condition for asset management purposes, based on automatic information collection and software for automatic analyses of this information. The objective of the work has been to address the opportunities and

challenges with using automatic methods for technical condition assessment for components in the distribution grid.

Condition monitoring for electricity distribution infrastructure can be considered within two coarse areas: monitoring of infrastructure corridors (e.g. for vegetation encroachment), and monitoring of the infrastructure itself (e.g. pylons, lines, and components). The state of the art for automatic monitoring of infrastructure corridors is quite advanced, with several commercial solutions available for accurately detecting and tracking the progress of encroaching vegetation using photogrammetry or LIDAR point cloud data. However, the state of the art within automatic monitoring of infrastructure and components is less mature. Recent Machine Learning approaches (e.g. Deep Learning) have shown fantastic performance within academic studies for identifying and classifying components and faults from unstructured data (e.g. images). The main barriers to industry adoption of these techniques are the time and labour required to collect, annotate, and maintain extensive training data sets as well as their reliance on high-quality imagery captured under good conditions.

Within both areas, input data is typically collected manually using a piloted aircraft. Drone technologies and the regulations associated with their use have now reached a level of maturity where it is more efficient to perform such data collection automatically. Future trends within automatic condition monitoring will therefore include the increased adoption of remotely operated aircraft for data collection, the emergence of commercial solutions for automatic condition assessment of infrastructure and components, as well as the adoption of new and more varied sensor types to extend the range of faults that are detectable and operational conditions.

Pole with a woodpecker damage. WP1 develops decision support methodologies for optimal planning and asset management for the future distribution grid. (Photo: Hafslund Nett)

Smart grid operation (WP2)

The *objective* of WP2 is to develop and test a set of new concepts and solutions that optimally utilize 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 standardized solutions.

Data gathering and -assembling from several smart meter HAN ports

A student master thesis work is in progress, with the title "Data gathering and - assembling from several smart meter HAN ports." This system will make an efficient system for collecting data from the distributed smart meters, transfer them to a cloud service and do a preliminary analysis of the assembled data from the different smart meters.

Survey of sensors

As part of the state of art study of sensors currently in use in today's distribution grid, a survey was developed and circulated to selected partners in CINELDI. The feedback from the survey will be important input to Romina Muka (PhD, starts January 2018) and her research in optimal deployment of sensors and controllers for the operation of the next generation distribution grid (with new intelligent electrical devices).

Co-simulations of power grid and communication network and services

The state of the art of co-simulations of power grid and communication network and services are investigated, and several proposed solutions and open questions are identified. The synchronization between the domain specific simulators, how to make the simulators be integrated in real time is one of the main challenges. The work is conducted by Fredrik Haugli (PhD from September) as part of his research plan to establish a modelling framework (potentially using simulation) to investigate the trade-off between centralised and distributed operation of the distribution grid.

Use cases for the future distribution grid

The work on Use Cases for the future distribution grid started with that the topic of interest was defined and justified by the partners (results from a survey and workshop 2018-06-22). Then, almost 240 Use Cases were reviewed by an expert group and narrowed down to 14 Use Cases which have been proposed for further development.

The work in the Expert Group has been initiated that will continue working of 3-4 selected use cases in 2018. It is on the agenda for a workshop planned for May 2018.

Security of smart meters and IoT devices for the electricity grid

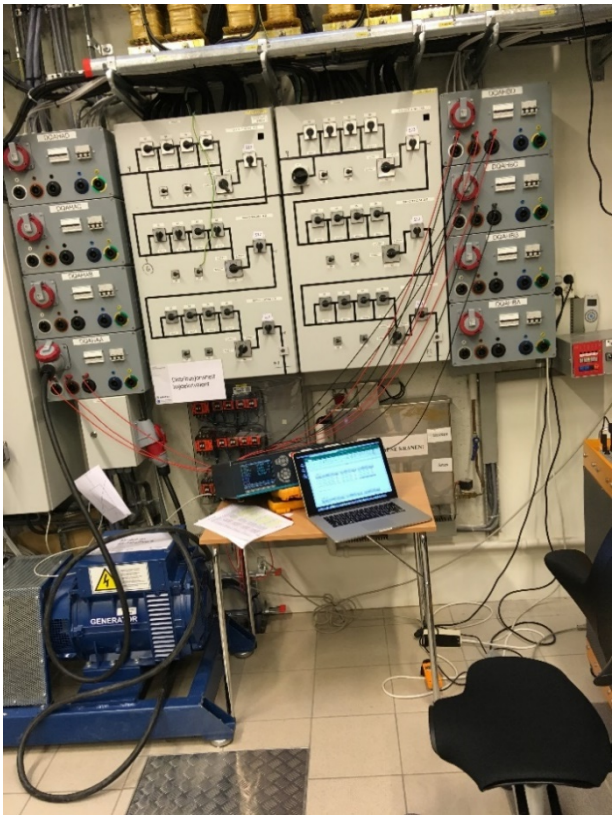
The main results from this activity is from the work of three master students on security of smart meters and IoT devices for the electricity grid. The master students are doing research on how the smart meter HAN port may be exploited by an attacker, and they are analysing the risks of adding IoT devices that interact with the smart grid within the ISO/IEC 27005 risk management framework.

A new concept for protection has been tested out in the Smart Grid Laboratory

CINELDI's first implementation of a use case in the laboratory: Hafslund Nett has proposed a new method for fault localization of short circuits in mesh-connected distribution networks.

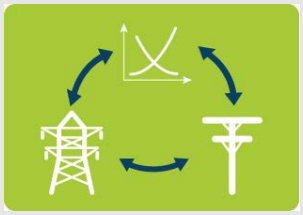
The implementation includes several preparing actions prior to actual testing of the novel concept in a controlled environment at the Smart Grid Laboratory (NTNU Campus). Three visiting representatives from R&D department at Hafslund Nett attended a one-day lab session, taking active part of the initial physical experiments in lab. Part of the concept was confirmed, but the actual calculation of fault location requires further in-depth research to account for non-ideal conditions, e.g. unbalanced network impedance.

Later, much of the work has focused on acquiring a more detailed and accurate characterization of the distribution grid model. Moreover, these data have been used to parametrize a simulation model, enabling parallel workflow of simulation and physical testing on lab. If proven as a viable concept, the use case will be considered to become a pilot project in CINELDI. The present work will be presented in two documents, a technical report related to the technical assessment and documentation of the distribution grid model. The second document will describe in-depth the Hafslund use case, along with generated research results and further recommendations.



WP2 experiment in the Norwegian Smart Grid Laboratory

Interaction DSO/TSO (WP3)



The *objectives* of WP3 are to develop concepts and solutions for utilizing flexible resources (DER)[1] in different market products and ancillary services, for increased observability between the distribution and transmission systems and business models regarding utilization 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.

2017 has been a year for start-up of the activities within WP3. The main activities are therefore related to a first workshop with the partners in CINELDI, a concept study of ancillary services and interaction DSO/TSO and recruitment of PhD students.

Workshop with partners – arranged in cooperation with WP4 and WP5 (2017-09-07)

A partner workshop was arranged in the beginning of September in cooperation with WP4 "Microgrids" and WP5 "Flexible resources in the distribution grid". The workshop was divided in two parts, where an introduction to each WP and input from selected partners were given in the first part, and group discussions related to the topics within the relevant WPs were performed in the second part of the workshop.

The results from the group discussions will give important information for the research to be done within WP3. Two groups were established discussing how flexible resources are in use today, how they can be used in near future (2020-2030) and after CINELDI (2030-2040), both for the market and in system services.

To a limited degree some flexible resources (mainly for large industry or electrical boilers) are in use in balancing services today – as tertiary reserve with response within 15 minutes, activated by a phone call from the TSO.

In the near future, there will be an increased focus on other flexible resources, but customer involvement is a challenge. The interaction DSO/TSO has to be defined, to make it possible to activate flexible resources without generating any problems for other stakeholders. This a topic that WP3 will study.

Concept study of ancillary services and interaction DSO/TSO

A concept study was started in 2017, evaluating today's ancillary services and interaction DSO/TSO. This work will be the basis for the evaluation of the ancillary services in the future intelligent and flexible power system (2030-2040). Topics to be evaluated are state of the art in Norway and other relevant countries (based on today's power system) for the interaction DSO/TSO. Present functionalities are in use to secure a stable operation of the power system, both on transmission and distribution level, and an evaluation of which problem(s) the different ancillary services should solve such as when are different services needed? When is there a problem to solve? And what should be the physical parameters to trigger the need for activating a service? (voltage, frequency and other).

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

This study will be completed in 2018. Important experiences from the Horizon 2020 project "SmartNet"[2] will be important input to this work, as this project also is included as in-kind to CINELDI.

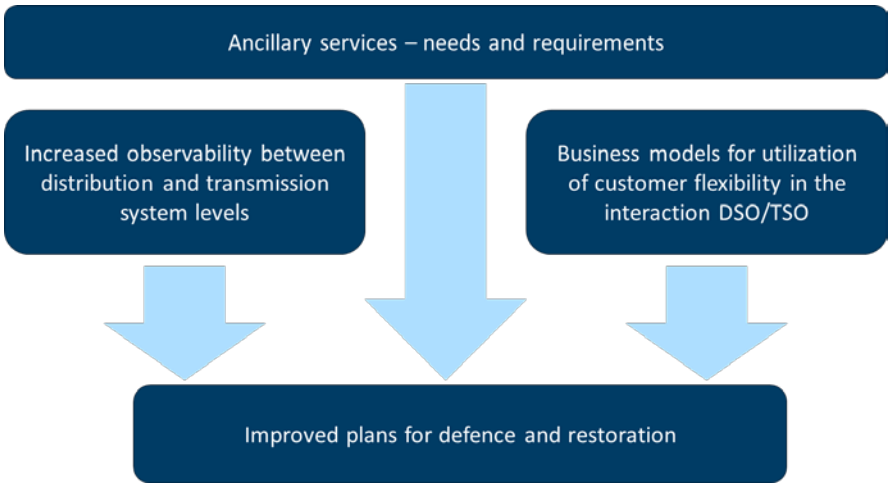
A survey for mapping the status of today's interaction between DSOs and TSO in Norway has been developed. The focus in the survey will be on the use of flexible resources in today's power system and what kind of information the DSOs are selected related to interaction DSO/TSO. The survey will be sent out to the DSOs in CINELDI in the beginning of 2018.

PhDs recruited

Two PhDs were recruited to WP3 in 2017, focusing on the following topics:

- **Distributed and hierarchical dynamic state estimation for smart distribution grids**
  The PhD will study accurate monitoring of the power system, while handling (or avoiding) the 'data deluge'. At substation level, detailed dynamical models will be utilized, with full utilization of sensor data. Information transmitted to higher voltage levels of the power system will be filtered to focus on information and system services of relevance to those higher levels. Methodology will need to be developed for sensor selection and placement for observability at the lower level, and for filtering and data fusion under consideration of the particular dynamic phenomena to be observed at higher levels.
- **Techno-economic optimization for analysing consumer flexibility and related market structures**
  The main objective of the PhD project is to develop models, concepts and solutions for utilization of customer flexibility in the energy system. This includes realization of balancing services and flexibility services as an alternative to grid reinforcement, minimizing grid asset investments and maintenance costs. The project will study market structures for trading flexibility, the different players, business models and decision support for the analysis of markets, contracts, tariffs and cooperation

The PhD students started up with their coursework in 2017, that will be continued in 2018. Additional, the PhD students in cooperation with their supervisors will start on the academic work related to each PhD topic.



Task structure in WP3

[2] http://smartnet-project.eu/

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.

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.

Demonstrating simplified reference system for microgrids on the smart grid laboratory

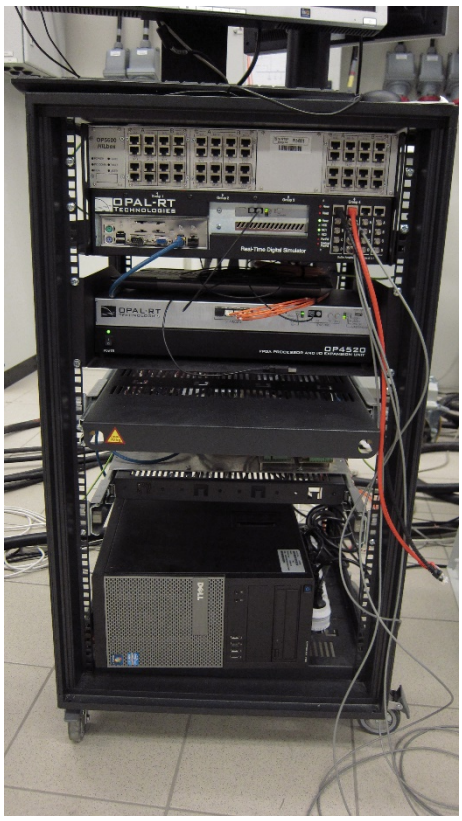
A simplified reference system for studying isolated microgrids has been defined. The reference system has been used for developing and testing primary control strategies, a droop control that ensures cooperative power sharing and harmonic sharing. One of the challenges is deriving a droop controller that works when the line feeder impedances change dynamically and varies from largely resistive to more inductive characteristics, and still obtain proper sharing of power and current harmonics.

This research has been driven forward through collaboration between PhD candidate Fredrik Göthner and two master students. The simplified reference converter system and associated cascaded controllers have been successfully implemented in simulation environment, supporting master thesis and PhD thesis work. A related paper entitled Considerations of Virtual Impedance Implementation in the Synchronous Reference Frame was authored by Fredrik Göthner and Raymundo E. Torres-Olguin, and accepted for IEEE Environment and Electrical Engineering conference.

Two contributing master projects are Improved Power Sharing in AC Microgrids by Using Decentralised Virtual Impedance Control, and Advanced Harmonic Sharing Techniques for Microgrid Applications. The research is in collaboration and supervision by Professor Dr. Olimpo Anaya-Lara from University of Strathclyde. Extensive laboratory activities are planned starting March 2018, the previous simulation work and promising results are input for a hardware-in-the-loop implementation at the Norwegian Smart Grid Laboratory. The plan is to utilize and demonstrate the advanced facilities available at the laboratory, with the help from research partners at NTNU and SINTEF Energy Research.

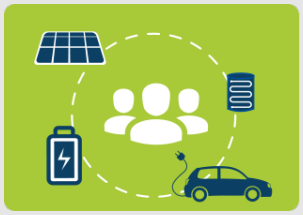
State-of-the-art review of protection in microgrids

Through the work WP4 is creating high-level use cases identifying important challenges for relay protection custom to microgrids. One use case description has been proposed Adaptive microgrid protection, and a state-of-the-art review on protection in microgrids has been started, forming the basis for further research. The WP4 microgrid work package will partly run in cooperation with WP2 supporting research of a PhD candidate focusing on 5G for Low-Latency, Secure and Dependable Communication Services for Fault Handlings.



Opal-RT Simulator to be used in the planned PhD experiments in the Norwegian Smart Grid Laboratory

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 utilizing flexibility as an important asset in the power system.

To pursue this goal, the work package is organised into four main Tasks:

- Grid flexibility categorisation and modelling
- Methods for sizing and placement of flexible resources
- Customers' involvement in flexibility
- Value of flexibility.

The major activities in the start of the year was to plan the research activities in detail, to recruit PhD candidates and to coordinate with the other CINELDI work packages as well as the relevant work within FME ZEN and FME CenSes. Moreover, the main achievements in 2017 are briefly described below.

Partner workshops on flexibility

At the 7th of September, we arranged a partner workshop together with WP3 and WP4, with focus on establishing good contact between the researchers and user partners, as well as discussing which technologies and solutions are most relevant to study in a 2030-2040 perspective. On the follow-up event during the CINELDI days 31st of October to 1st of November, we established the foundation for 3 pilots on flexibility, together with the user partners:

- Pilot 1: “Flexibility used in system operation”
- Pilot 2: “Flexibility as alternative to distribution grid reinforcements”
- Pilot 3: “Green and flexible end-users”.

These pilots will be important assets for testing out the usefulness and relevance of new simulation models, planning methods business models etc. that will be developed as part of the research.

Energy Modelling workshop and 5th Pyomofest

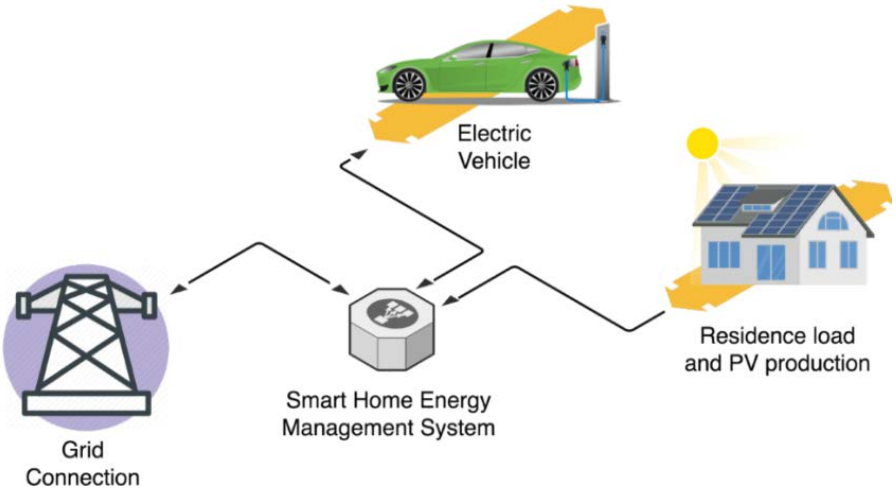
Together with our international research partner Sandia National Labs, we arranged this workshop 3rd -5th of October in Trondheim, with around 50-60 national and international participants from academia, research and private sector. The main objective for the workshop was to gather scholars, researchers and analysts working with mathematical modelling and optimization of energy systems such as energy storage optimization and EV integration, with a special focus on the open-source programming languages Python and Pyomo.

Master theses on flexibility

Well-planned master theses can be key to establish a successful link between research and education. Regarding the FME’s, the master theses serves more important purposes, as the user partners also can be actively involved in the process. We decided to “kick-start” the research by establishing 14 master theses at Dept. of Electric Power Engineering (NTNU) that are connected to the WP5 research for the years 2017 and 2018.

Other research highlights from 2017

- Successful power-hardware-in-the-loop tests of EV power grid interface in the SmartGrid lab (DTU-SINTEF-NTNU collaboration).
- Development of dynamic AC-power flow model with storage and EVs (Matlab model).
- Abstract accepted for special issue of “Sosiologisk Tidsskrift”. Working title: det fleksible mennesket 2.0.
- Developed optimization models for prosumers (with PV, EV and storage) based on stochastic and deterministic dynamic programming (Matlab-models).
- Assessments of grid tariff structures for prosumers (MSc theses at NTNU).
- Assessments of how energy storage can exercise market power in small power systems (MSC thesis at NTNU).
- Three scientific papers were presented at international conferences:
  - "Stochastic Optimization of PV Battery System Operation Strategy under different Utility Tariff Structures". Int. Workshop on Integration of Solar Power into Power Systems 2017.
  - "Guidelines for DSOs on Reactive Power Provision by Electric Vehicles in Low Voltage Grids". CIRED 2017.
  - "Integration of PEV and PV in Norway Using Multi-Period ACOPF — Case Study". IEEE PowerTech 2017.



Electric vehicles can provide flexibility for the grid and the end-user
(From the MSc thesis by S. Bjarghov, 2017, Dept. of Electric Power Engineering, NTNU)

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 a structured multidisciplinary research, providing results that are robust to external requirements and opportunities for the future distribution system. WP6 will establish a common basis for the various work packages regarding the future distribution grid, while providing direction for research in CINELDI.

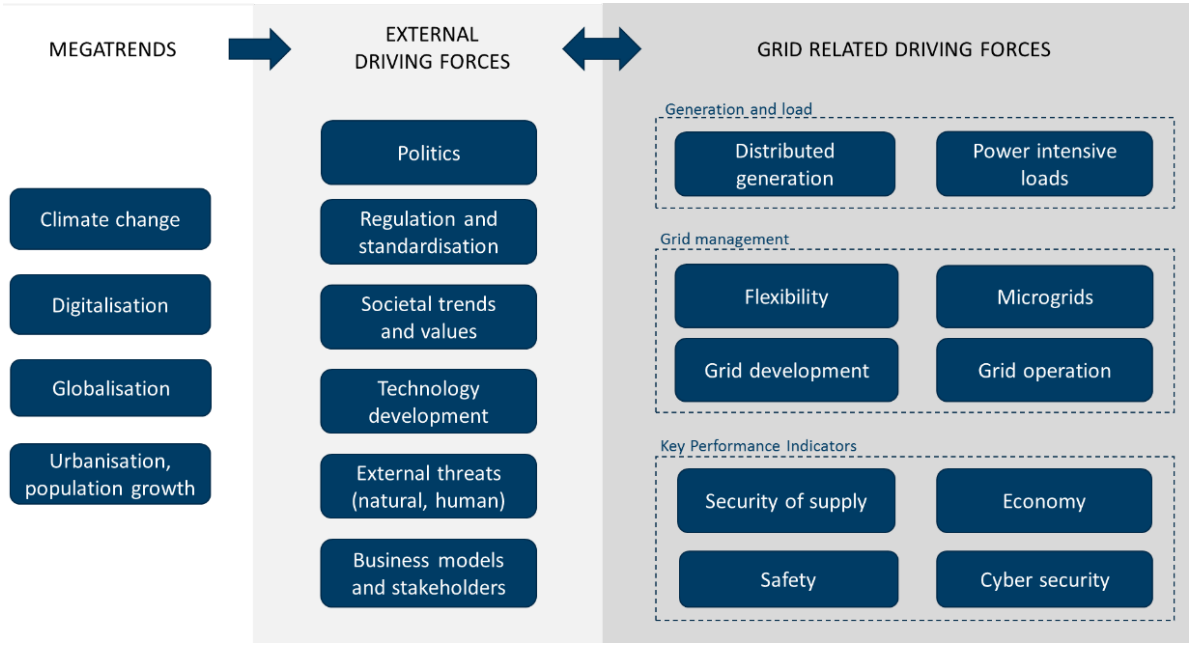
Foresight process developing scenarios

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, develops a set of credible scenarios for the electricity distribution system in Norway.

The work on scenarios is performed as a foresight process through workshops and meetings gathering all partners in CINELDI, supported with literature surveys and further studies. In the first workshop that was arranged during kick-off of CINELDI in fall 2016, a stakeholder analysis was performed.

Driving forces for intelligent electricity distribution system innovation

In May 2017, a workshop was arranged discussing drivers, barriers and enablers for intelligent electricity distribution system innovation, with almost 60 participants from the research and user partners. The workshop has been supplemented with literature studies on driving forces, previous similar projects and other countries' roadmaps. The driving forces have been furthered structured into megatrends, external factors and internal grid related factors, as shown in the figure.



Driving forces structured into megatrends, external factors and internal grid related factors

Mini scenarios for the future distribution system

The third workshop was arranged in August, with group discussions on mini scenarios. A mini scenario is a probable event, development or action of significance for the future electricity distribution. It is related to one or more driving forces. This work resulted in 113 mini scenarios later adapted into 60 mini scenarios. Examples of mini scenarios:

The consumer is self-contained
The consumer (prosumer) produces most of its electricity use, with the grid as backup. The grid companies have poor foundation for utility. The grid is poorly utilised as it's only function is as backup.

Self-healing grid
Good incentives for investments in fault current sensors and remotely controlled disconnectors lead to an automated distribution grid. Grid faults leading to interruptions, are automatically isolated. Reduced interruption costs.

Battery in every home
Power based tariffs give incentives for levelling out the power use. Batteries reduce the maximum load. Seen from the grid, the consumer has a uniform consumption.

The next step is based on the mini scenarios to develop a credible set of visions and scenarios for the future flexible and intelligent distribution system in Norway.

Pilot projects in CINELDI

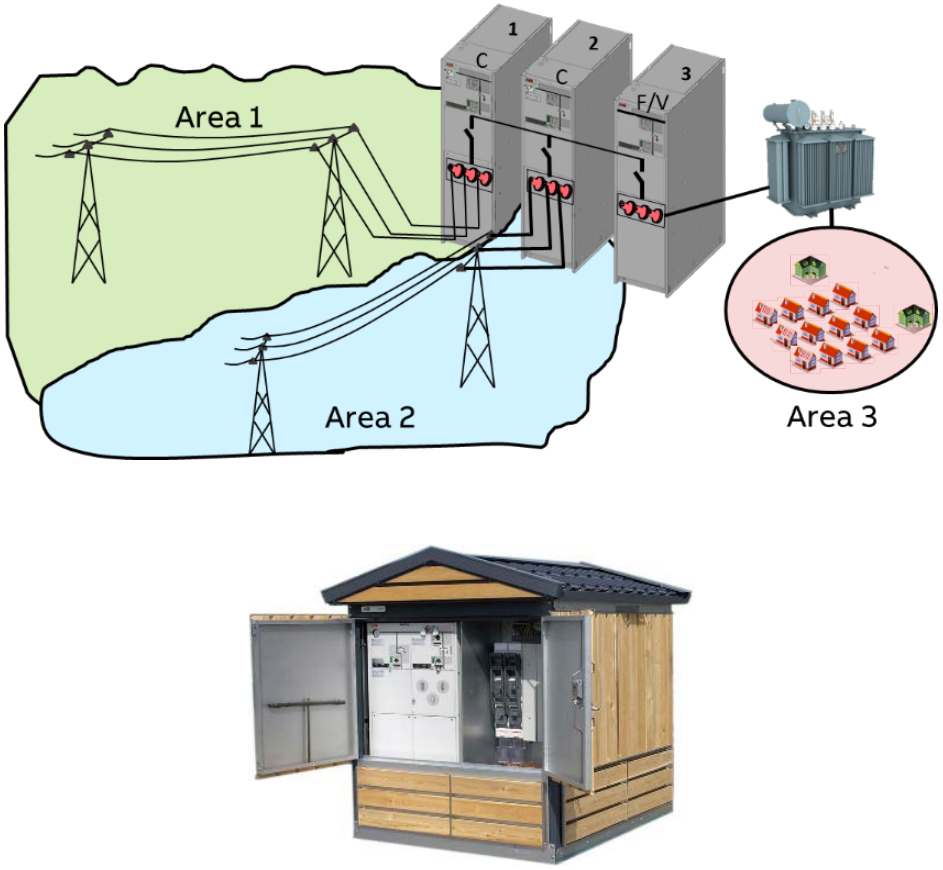
CINELDI will develop knowledge, methods, and tools that will be tested in laboratories, simulated environments, and small-scale field pilots. The pilot projects are as such important parts of CINELDI and will be an integrated part of the research and development in the FME.

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.

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 2018 work plan.

Examples of pilot projects that have already been launched are Smart Cable Guard for condition monitoring of cables, and testing of a new protection concept in the Smart Grid laboratory. Hafslund Nett is responsible for these.

"The future digital substation" is another pilot project under planning, involving several user partners. This pilot project will be performed by ABB, in collaboration with research partners and several grid companies in the consortium.



The future digital substation - a pilot project planned within CINELDI (Source: ABB)

Selected Cases

Energy Modelling workshop and 5th Pyomofest

From October 3rd -5th 2017, WP5 in CINELDI arranged the 5th workshop on the open-source optimization modelling language Pyomo (the so-called Pyomofest), followed by a full-day workshop on energy systems modelling and optimization. The workshop was a result of a collaboration between NTNU, CINELDI and our international research partners Sandia National Labs and UC Davis.

Introduction to the Pyomofest workshop within WP5, October 2017

The purpose of the workshop was three-fold:

- To provide an opportunity for Pyomo developers and users within energy systems and grid modelling to share their collective experiences.
- To give PhD students, researchers and analysts an excellent opportunity to present their research to other experts on mathematical modelling and optimization of energy systems
- To give all attendees an inspiring meeting place to discuss possibilities for further modelling development and research collaboration.

Pyomo is a Python-based open-source software package. It supports a diverse set of optimization capabilities for formulating, solving, and analysing general optimization models, and has gained increasing interest and use the last years. This was evident from the interest for the workshop – we ended up with more than 50 participants, around twice of what we initially expected. The participants came from universities, research institutes, public bodies and private sector. Most were from Norway, but we also had participants from universities in the US, UK, Netherlands, Germany and Austria.

The workshop kicked off with a short tutorial on Pyomo modelling. It was followed by presentations and discussions on how to use Pyomo to model and optimize energy systems in general, and smart grids systems in particular. On the last day, 13 of the participants presented their own model-based research from PhD projects and research projects at NTNU, SINTEF, UC Davis, Sandia, Univ. of Michigan, Fraunhofer, and Imperial College.

Distribution system planning and partner involvement

The future electricity distribution system will include new intelligent devices and flexible resources, resulting in new load and generation patterns as well as massive amounts of operational data. Many changes will be customer driven, and new uncertainties will emerge for the distribution system operators (DSOs), making planning of "future proof" distribution systems more challenging.

In CINELDI Work Package 1: Smart Grid Development and Asset Management, we are developing methods, models and tools to support cost-benefit, optimised and risk based planning of the future active distribution system.

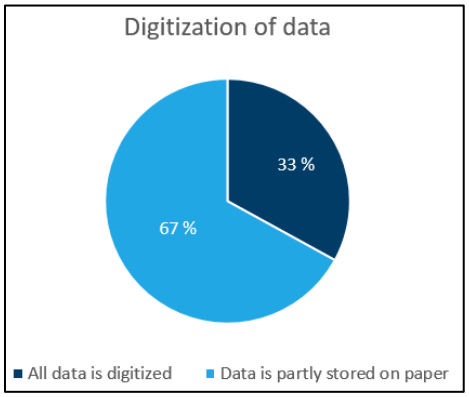
The starting point for this work is to establish a description, both regarding today's practice in the industry, and regarding what methodologies and tools that are available from previous research. This state of the art description is used as basis for identifying the needs and gaps, both in terms of what methodologies that need to be developed in CINELDI, and how the methodologies should be designed for the DSOs to implement them.

To get an overview of today's practice in the DSOs regarding grid planning methodologies and tools, a questionnaire was sent to the DSO partners. The results show that different implementations in Excel, as well as Powel's Netbas are the most common tools used for analyses for grid planning purposes. The DSOs lack good tools to consider new aspects such as prosumers, end user flexibility, distributed storage and variable generation (PV, wind) in their planning. Uncertainties are only to a limited extent accounted for.

Many of the DSOs indicate that the main reason why more analyses are not carried out as part of the grid planning process, is that they do not have sufficient high-quality input data. It was found that parts of the grid data are still stored on paper at 67% of the respondents (9 DSOs in total). They are in the process of digitizing these data.

The results from the questionnaire were presented and discussed in a workshop on distribution system planning, held in June 2017, to ensure relevance for the industry. Some of the DSO partners presented challenges and opportunities in distribution system planning. The workshop also included group work, where the partners were invited to give input to the WP1 work plan and focus areas, based on their experience.

Partner involvement is essential when developing models, methods and tools for the future distribution system planning. It's essential both to ensure ownership in the methodology to be developed, and eventually to ease the implementation in the DSOs to support the transition to the future flexible and intelligent distribution grid.



33% of the DSOs that answered the questionnaire have all grid data digitized, while 67% of the DSOs still have grid data partly stored on paper.

Workshop on distribution system planning, June 2017.

Data gathering and -assembling from several smart meter HAN ports

A student master thesis titled "Data gathering and -assembling from several smart meter HAN ports" is in progress. This system will make an efficient system for collecting real-time data from the HAN (home area network) port of distributed smart meters. The information is then transferred to a cloud service for a preliminary analysis of the assembled data.

Smart meter neighbourhoods

Normally, the real-time data from the smart meters are used for analysing the in-house consumption and for in-house energy management systems. However, by analysing real-time data from several smart meters in a neighbourhood, information about the condition of the outdoor connecting grid can be extracted. As the smart meters are installed in the grid already due to fiscal reasons, these measurements are "nearly free".

Transformer station with connected houses, all with smart meters transferring real-time data via modems to a cloud service for analyses.

The real-time data from the smart meters can reveal if there is an irregular mismatch between energy from the transformer station and the sum of energy flow in or out of the houses. Further, the measurements will tell how the voltage varies along the line. This is especially of interest for long lines with prosumers connected to the grid. Depending on which measurements are available on the HAN port on real-time basis, other superior information can be extracted from the sketched system, to the benefit of the utility company.

Master thesis focus

The master thesis focuses on the embedded system enabling the real-time data gathering and -assembling from the HAN ports. The described analysis will be implemented just to illustrate the use of the system. Currently, most of the bricks forming a complete system are developed and demonstrated:

- 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.
- A simple graphical user interface for displaying the voltage as a function of location along the line.

The remaining work will consist of stitching together the modules, duplicating the equipment and then test the system in real environment, i.e., in a real grid with measurements from all smart meters on a power line from a transformer station.

International Cooperation

Scientific committee (SC)

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

- Professor Morten Hovd, NTNU, Norway
- 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.

The first meeting in the SC was held in September in Trondheim. Before the meeting, a side event to the Smart Grid Conference was arranged, where the members of the SC presented their institutions' activities within the smart grid area.

International workshops

October 27th, WP1 arranged a workshop with professor Fabrizio Pilo from University of Cagliari. SINTEF and NTNU researchers attended the workshop, where information about previous and ongoing work was exchanged, and areas and activities for further cooperation was identified.

October 3-5th, WP5 arranged a Pyomo workshop about "Flexible modelling of optimisation problems in Python" together with Sandia National Laboratories and UCDavis, USA. Approx. 40 participants attended the workshop. WP5 has also arranged several meetings with MTU (Bruce Mork and Samit Pudyal) to plan further cooperation related to WP5.

CINELDI has ongoing cooperation with DTU related to integration of electric vehicles as a flexible resource (WP5). DTU research fellow Antonio Zecchino stayed at NTNU in June 2017, where he ran tests in the Smart Grid laboratory. This cooperation is now taken further in a joint paper.

Cooperation with international projects

CINELDI has established cooperation with several EU projects, both within FP7 (ELECTRA IRP) and H2020 (SmartNet and INVADE). The SmartNet project is strongly related to WP3 in CINELDI, and WP5 collaborates with the INVADE project. SmartGrid Services Cluster by Enoco is a partner in the H2020 EU-SysFlex project, which is relevant for WP3.

CINELDI also collaborates with the ERA-Net SG+ project SmartGuide. Furthermore, CINELDI will strengthen the cooperation with ETIP SNET and works together with EERA JP Smart Grids through participation from SINTEF Energy Research and NTNU, contributing to alignment of research and innovation priorities in Europe within Smart Grids.

CINELDI will also collaborate with the newly granted ROME project within microgrids, under the India-Norway R&D program on smart grids (CINELDI partners SINTEF Digital and NTNU amongst others).

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:

- Global Smart Grid Federation: Kjell Sand is board member.
- IEC TC8, IEC System Committee Smart Energy, and CENELEC TC8X: Kjell Sand is a member of the International Standardisation Committees
- ETIP SNET: Grete Coldevin is co-chair in the National Stakeholders Coordination Group.
- ISGAN: Grete Coldevin is a 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.
- IEEE Innovative Smart Grid Technologies (ISGT) Europe 2018: Gerd Kjølle is a member 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.

Recruitment

During 2017 5 PhD students and 1 Post Doc have been recruited. The first started in March and the rest during the autumn. Additionally, 3 PhDs are recruited and will start their work during 2018. CINELDI is still working with the recruitment of PhDs/PostDocs, aiming for 9 PhDs and 2 PostDocs during the first research phase.

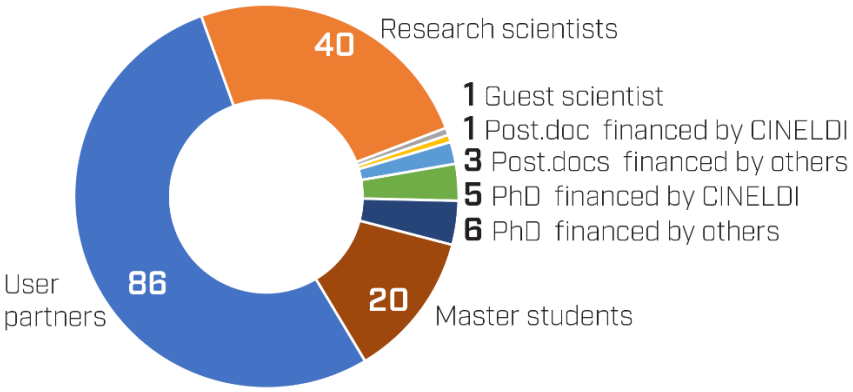
Overview of recruited PhDs and PostDocs within CINELDI

Name	Period	WP	Position	Title
Romina Muka	2018-2022	WP2	PhD	Self-Healing and Autonomous Smart Grid Operation
Fredrik Bakkevig Haugli	2017-2021	WP2	PhD	Distributed and centralized control to support smart grid operation with high quality in a cost-efficient way
Mohammad Ali Abooshahab	2017-2020	WP3	PhD	Distributed and hierarchical dynamic state estimation for smart distribution grids
Güray Kara	2017-2020	WP3	PhD	Techno-economic optimization for analysing consumer flexibility and related market structures
Kalpanie Mendis	2018-2022	WP4	PhD	5G for Low-Latency, Secure, and Dependable Communication Services for Fault Handling in Micro Grids
Fredrik Göthner	2017-2020	WP4	PhD	Smart power control in microgrids with modern power converters
Kasper Thorvaldsen	2018-2021	WP5	PhD	The value of buildings' energy flexibility in the power market
Ingvild Firman Fjellså	2017-2020	WP5	PhD	Understanding mechanisms and incentives for motivating user flexibility
Mario Blazquez de Paz	2017-2019	WP6	PostDoc	Modelling transition strategies towards smart distribution grids (Postdoc)

In 2017, 162 persons were involved in CINELDI in total, as shown below. 40 researchers from SINTEF Energy Research, NTNU and SINTEF Digital participated in the work (including centre management), and 86 representatives from the 26 user partners were involved. Among the students related to NTNU, there were 5 PhDs and 1 PostDoc funded by the CINEDI centre, and 6 PhDs and 3 PostDocs cooperating with CINELDI, with funding from other sources. 1 Guest researcher cooperated with CINELDI in 2017.

At NTNU, 20 master students were related to CINELDI, of which 3 delivered their thesis in 2017. The other students worked on their project theses during the autumn 2017 and will deliver their master thesis during 2018.

Among the researchers and students, the gender distribution was 75% men vs. 25% women. Among the researchers there were 28% women, and among the master students there were 35% women. The share of women among the PhDs/PostDocs funded by CINELDI is only 16.7% (1 out of 6 in 2017), and there were only men among the PhDs/PostDocs funded by other resources and the guest researcher.



Number of persons involved in CINELDI in 2017.

Communication and Dissemination

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.

Communication in numbers

- Media contributions and blogs: 14
- Newsletters: 3

Communication channels

Web

The CINELDI web www.cineldi.no was launched in 2016. The webpage provides open information from the centre.

- The web has had 2 027 unique visitors.
- There have been 5 592 views on the webpages.
- Visitors to the webpage come mainly from Norway, Bangladesh, Iran, Pakistan, India, United States, Italy, Sweden, Germany and France.

Media contributions

Energiteknikk nr. 7, November 2017

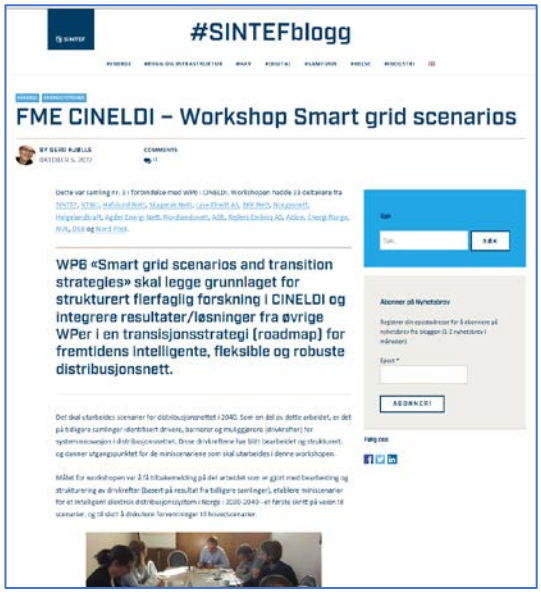
www.sintef.no, 20. October 2017	Cybersikkerhet og strømnettet
Energi og Klima, 11. January 2017	Elbilen en brikke i det fornybare energisystemet
energiteknikk	
13. September 2017	Setter smart by på dagsorden
5. September 2017	Sikter seg inn mot framtiden
13. Mars 2017	Ut i verden med norske energiløsninger
24. Mars 2017	Lanserer Skagerak Energilab
Lysenett.no	FME CINELDI
ABB	Facebook

Blogs

CINELDI has contributed with 4 blogs in 2017:

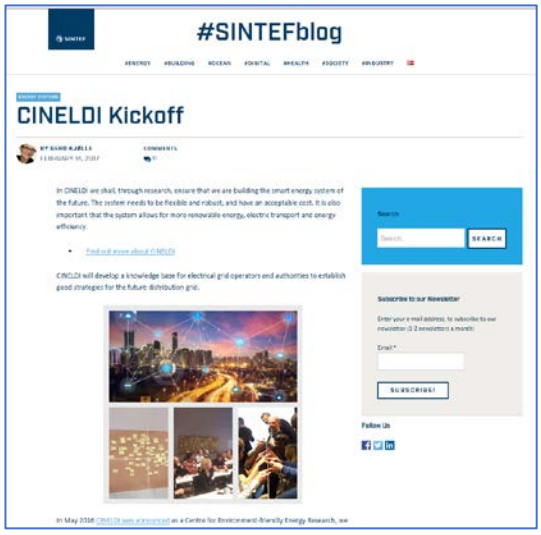
#SINTEFblog 2017-10-05
FME CINELDI Workshop – Interaction DSO/TSO, Microgrids og Flexible resources in the power system

#SINTEFblog 2017-10-05
FME CINELDI – Workshop Smart grid scenarios



#SINTEFblog 2017-11-15
De første CINELDI-dagene er gjennomført

#SINTEFblog 2017-02-14
CINELDI Kickoff



APPENDICES

A1. 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
Boye A. Høverstad	SINTEF Energi AS	Smart grid operation
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
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	Stiftelsen SINTEF, ved SINTEF Digital	Smart grid development and asset management
Christian Frøystad	Stiftelsen SINTEF, ved SINTEF Digital	Smart grid operation
Sture Holmstrøm	Stiftelsen SINTEF, ved SINTEF Digital	Microgrids
Martin G. Jaatun	Stiftelsen SINTEF, ved SINTEF Digital	Smart grid operation
Geir Mathisen	Stiftelsen SINTEF, ved SINTEF Digital	Smart grid operation
Marie Moe	Stiftelsen SINTEF, ved SINTEF Digital	Smart grid operation
Richard Moore	Stiftelsen SINTEF, ved SINTEF Digital	Smart grid development and asset management
Helene Schulerud	Stiftelsen SINTEF, ved SINTEF Digital	Smart grid development and asset management
Ketil Stølen	Stiftelsen SINTEF, ved SINTEF Digital	Smart grid development and asset management
Kristoffer Gregertsen	Stiftelsen SINTEF, ved SINTEF Digital	Interaction DSO/TSO
Giancarlo Marafioti	Stiftelsen SINTEF, ved SINTEF Digital	Flexible resources in the power system

Visiting Researchers

Name	Affiliation	Nationality	Sex	Duration	Topic
Antonio	Zecchino	Italy	M	Spring 2017	EV flexibility, smartgrids lab

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

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 Abooshabab	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

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

Name	Funding	Nationality	Period	Sex	Topic
Erling Tønne	Industrial PhD	Norway	2011-2017	M	Planning of Future Smart and Active distribution grids
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
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)

Master degrees

Name	Sex	Topic
Jørgen S. Erdal	M	Stochastic Optimisation of Battery System Operation Strategy under different Utility Tariff Structures
Sigurd N. Bjarghov	M	Utilizing EV Batteries as a Flexible Resource at End-user Level
Vegard S. Bjerketvedt	M	Analysis of the Role of Energy Storage in Power Markets with Strategic Players
Martin Lillebo	M	Optimal Sizing and Scheduling of Distributed Battery Storage Possibilities in RES Dominated Power System (2017-2018)
Thea Ulrikke Øverli	F	Fleksibelt forbruk som en ressurs i fremtidens kraftsystem (2017-2018)
Signe Gjørven	F	Integrasjon av sol i det norske kraftsystemet (2017-2018)
Aurora Flataker	F	Dynamic optimal power flow for distribution systems with energy storage (2018)
Adrian Cruz	M	Smart Charging of Electric Vehicles with minimized Grid Impacts (2017-2018)
Sondre Harbo	M	Agent Based Modelling and Simulation of Plug-in Electric Vehicles (2017-2018)
Ingrid M. Andersen	F	Stochastic optimization of Zero Emission Neighbourhoods in smart cities, utilizing flexible demand, PV and electric vehicles (2017-2018)
Fredrik Blom	M	A Market-Based Mechanism on Distributed Flexibility Trading (2017-2018)
Elise Tveita	F	Cost-benefit allocation of flexibility options in distribution systems (2017-2018)
Oda Andrea Hjelme	F	Integrasjon av distribuert fornybar energi I Trøndelag (2017-2018)
Jarand Hole	M	Integrasjon av distribuert fornybar energi I Trøndelag (2017-2018)
Anders Holvik	M	Virtual impedance in AC microgrids
Ruben Buchmann	M	Real-time platform for AC microgrids
Isa Agnete Halmøy Fredriksen	F	Exploiting the HAN-port for fun and profit
Henrik Willet	M	Exploiting the HAN-port for fun and profit
Edem Evevor	M	Smart Grid security in the IoT world
Amandeep Singh Virdi	M	Protect your privacy in big electrical data

A2. Statement of Accounts

Funding (kNOK)

	Funding	In-kind	Sum
The Research Council	3 616,7		3 616,7
The Host Institution (SINTEF Energi AS)		2 952,0	2 952,0
Research Partners			
NTNU		2 808,4	2 808,4
SINTEF Digital		1 334,0	1 334,0
Enterprise partners			
Distribution System Operator	7 600,3	4 139,0	11 739,3
Transmission System Operator & Market Operator	575,6	304,6	880,3
Vendors	633,2	2 478,8	3 112,0
Member organisations	230,3	269,6	499,9
Public partners			
Authorities	360,5	253,0	613,5
Sum	13 016,6	14 539,4	27 556,0
Costs			
The Host Institution (SINTEF Energi AS)			11 304,5
Research Partners			8 806,5
Enterprise partners			7 192,1
Public partners			253,0
Equipment			0
Sum			27 556,0

A3. Publications

Journal Papers

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

Published Conference Papers

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

Reports

Jørgen S. Erdal, *Stochastic Optimisation of Battery System Operation Strategy under different Utility Tariff Structures,* MSc thesis NTNU 2017

Sigurd N. Bjarghov *Utilizing EV Batteries as a Flexible Resource at End-user Level*, MSc thesis NTNU 2017

Vegard S. Bjerketvedt, *Analysis of the Role of Energy Storage in Power Markets with Strategic Players*, MSc thesis NTNU 2017

CINELDI will ensure that we are building the smart energy system of the future

- CINELDI will contribute to designing the future's flexible and robust electrical distribution grid at an acceptable cost.
- CINELDI will facilitate renewable energy, electrification of transport and more efficient use of energy.

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

The Research Council of Norway

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