CINELDI

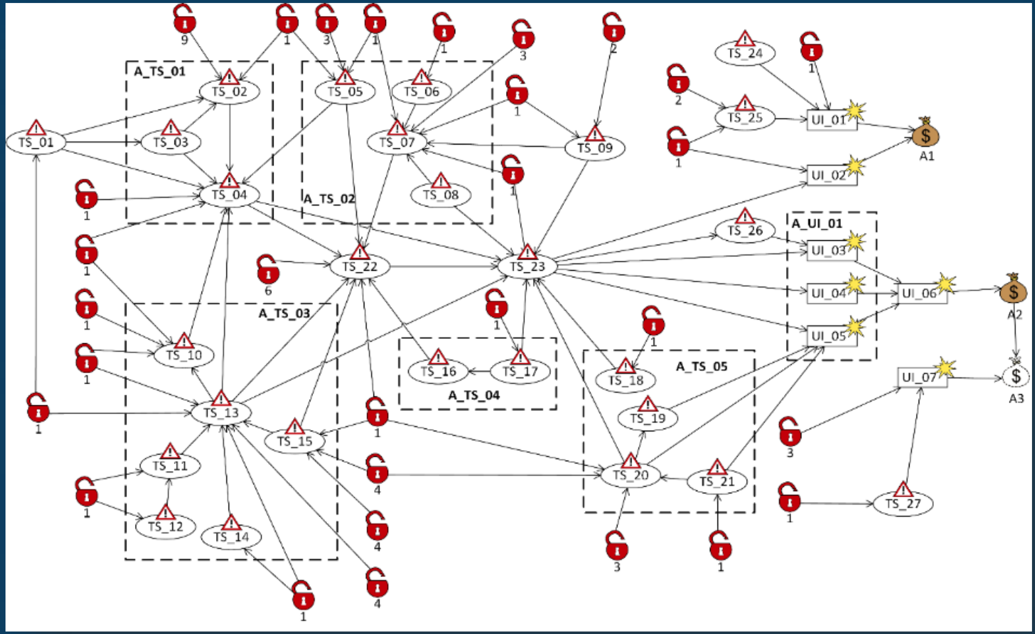
Centre for intelligent electricity distribution
- to empower the future Smart Grid

Selected CINELDI Results 2018

CINELDI result: Method for Identification and Modelling of Cybersecurity Risks in the Context of Smart Power Grids

Challenge and objective:

- Smart grids introduce new vulnerabilities and risks.
- Risk analysis of cybersecurity particularly demanding due to interdisciplinary nature – existing state-of-the-art challenged.



Omerovic, A. et. Al, 2019

Work performed:

- Implemented a model for qualitative risk analysis of cyber risk in smart grids based on parts of "CORAS" method risk analysis.
- Tested on an installation of self-healing functionality at a CINELDI DSO partner.

Significant result:

- A customized four-step approach to identification and modelling of cybersecurity risks in the context of smart power grids.

Impact for distribution system innovation:

- Improved security of supply enabled by improved risk understanding and management.

References in CINELDI:

- A. Omerovic et.al.: "A Feasibility Study of a Method for Identification and Modelling of Cybersecurity Risks in the Context of Smart Power Grids", paper to be presented at COMPLEXIS 2019

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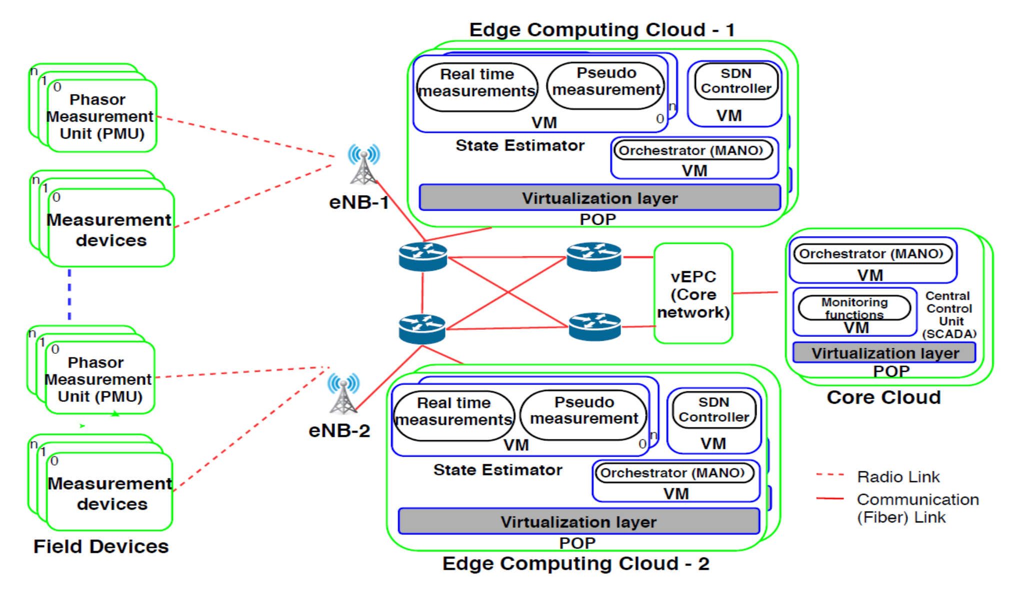
CINELDI result: Method and tool for analysing the performance and dependability of advanced communication technologies

Challenge and objective:

- Real time monitoring and control required due to large scale introduction of DERs.
- Such monitoring and state estimation systems have strong requirements on communication latency, reliability and security.



Amare, T. et. al, 2019

Work performed:

- Implemented a method of analysing performance of advanced communication technologies.

Significant results:

- A software tool , based on Möbius linked to external libraries, to analyse the impact of communication failures on the state estimation.
- The application is demonstrated through a case study.

Impact for distribution system innovation:

- Improved security of supply by accounting for the communication system performance.

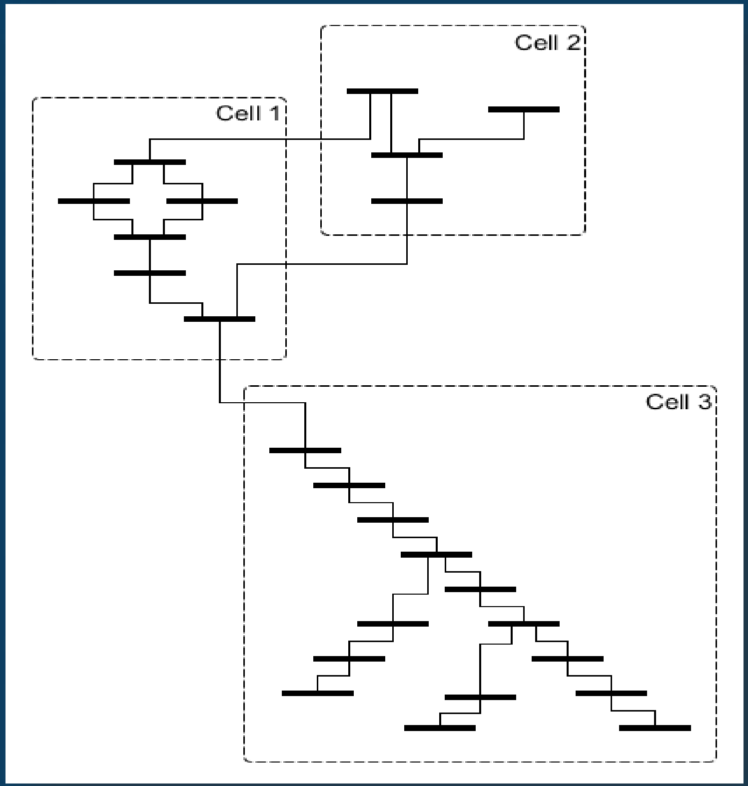
References in CINELDI:

- T. Amare et.al: "Dependability Modeling and Analysis of 5G Based Monitoring System in Distribution Grids", paper presented at VALUETOOLS 2019

CINELDI result: Use of flexible resources in grid operation – today and in the future (2030/2040)

Challenge and objective:

- Increased need for monitoring and control in operation of the future power system. Use of flexible resources and Web-of-Cells in grid operation.



Web-of-Cells example (FP7 IRP ELECTRA)

Work performed:

- Survey among DSOs participating in CINELDI.
- Development of a novel control architecture concept (Web-of-Cells/ELECTRA).

Significant results:

- A larger variety of flexible demand units is expected in the future – both type of demand and customer. Aggregators are needed to utilize smaller units.
- Hydrogen-fuelled systems, PV panels and wind turbines will be used for voltage regulation and balancing services.
- The availability of energy storage will increase towards 2030/2040.

Impact for distribution system innovation:

- A new control architecture for utilizing flexible resources in grid.

Reference in CINELDI:

- H. Sæle, A. Morch, E. Rikos, S.M.C.S. Maria and M. Kosmecki: "Utilization of distributed energy resources' flexibility in power system operation - Evaluation of today's status and description of a future concept", IEEE UPEC 2018

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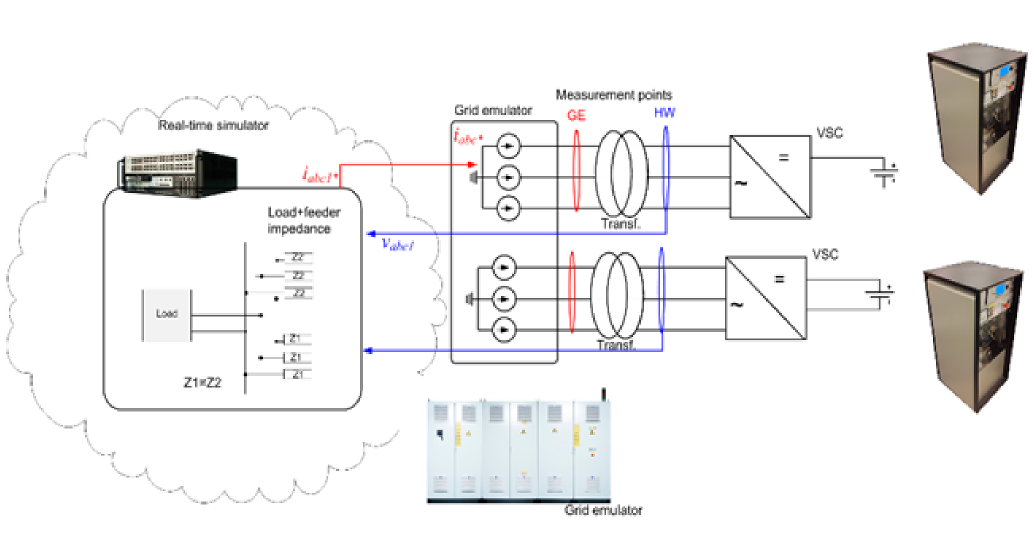
CINELDI result: Real-time power hardware-in-the-loop simulation platform to evaluate ancillary services in microgrids

Challenge and objective:

- Smart grids is a game changer in the distribution grids.
- Prototype equipment and functions have to be tested and verified in a controlled, safe and realistic environment.



Work performed:

- A power-hardware-in-the-loop setup is under development.
- A building block for the proposed "Real-time power hardware-in-the-loop simulation platform to evaluate ancillary services in microgrids".

Significant result:

- The setup is able to operate one converter with an emulated load, a synchronization mechanism is needed to connect the other converter.

Impact for distribution system innovation:

- Safe and realistic testing of new equipment before installation.

Reference in CINELDI:

- Conference papers / Demonstration of the smart grid lab capabilities on Power Hardware-in-the-loop using an example of voltage collapse with converters connected in distribution grids.

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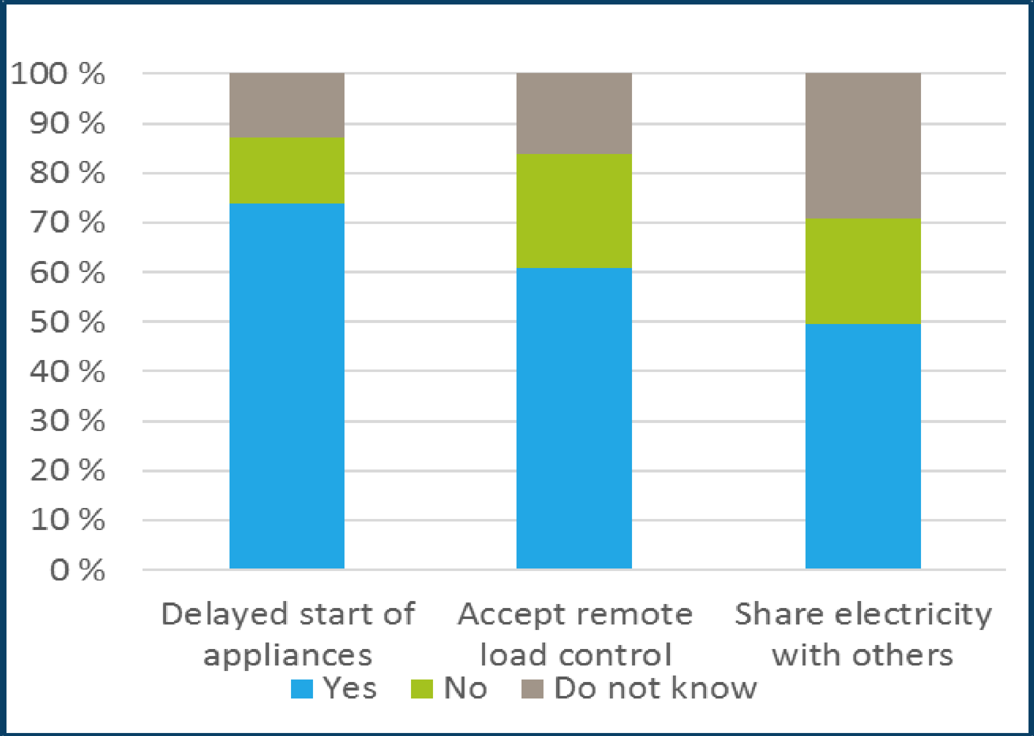
CINELDI result: Potential for household flexibility

Challenge and objective:

- Capacity problems in the grid due to increased peak load. Identify potential for household flexibility.



Work performed:

- A survey among a representative sample of Norwegian households (2017).

Significant results:

- 3 out of 4 are willing to delay the start of washing machine, dishwasher etc.
- 2 out of 3 will accept remote load control of their water heater.
- 50% will share the available electricity with others, by manual reduction.

Impact for distribution system innovation:

- Reduced peak loads and reduced need for new investments.

References in CINELDI:

- A chronicle describing the households customers' evaluation of their potential for flexibility, published in Dagens Næringsliv 21 September, Gemini.no and KS Bedrift Energi.

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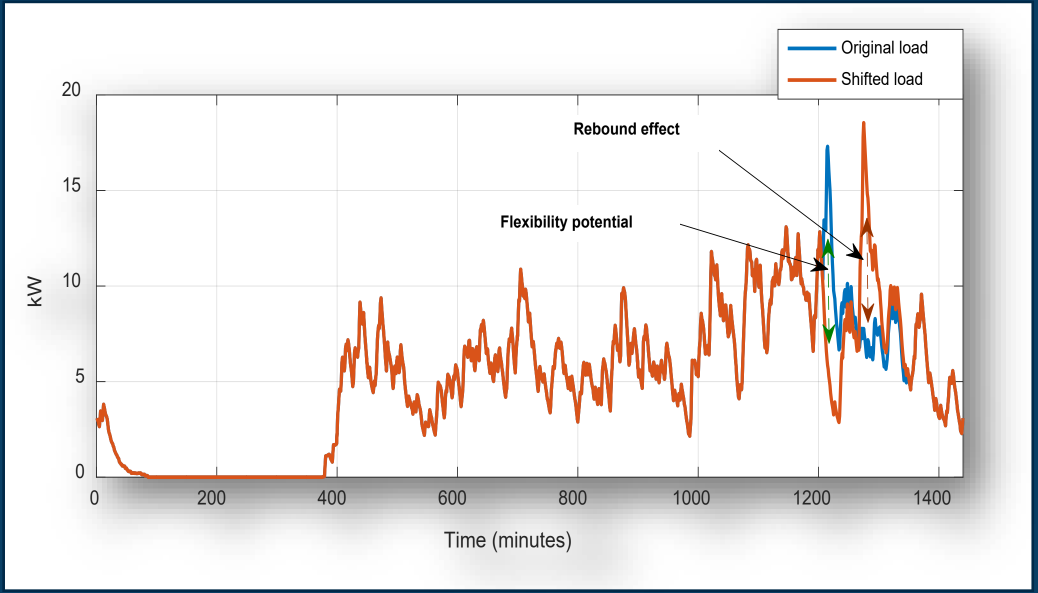
CINELDI result: Flexibility modelling method for atomic loads

Challenge and objective:

- Capacity problems in the grid due to increased peak load. Identify potential for flexibility and possible rebound effect among atomic loads (washing machines, dishwashers etc.)



Impact of shifting activity for 100 households where all of them have at least one time appliance use at the particular day.

Work performed:

- Development of a data-driven flexibility modelling method for shiftable atomic loads, based on 1-minutes measurement of electrical appliances.

Significant result:

- Shifting of all cloth washing activities planned between 20:00-20:15 to 21:00-21:15 resulted in flexibility potential of 11.5 kW for 100 households.

Impact for distribution system innovation:

- Reduced peak loads and reduced need for new grid investments.

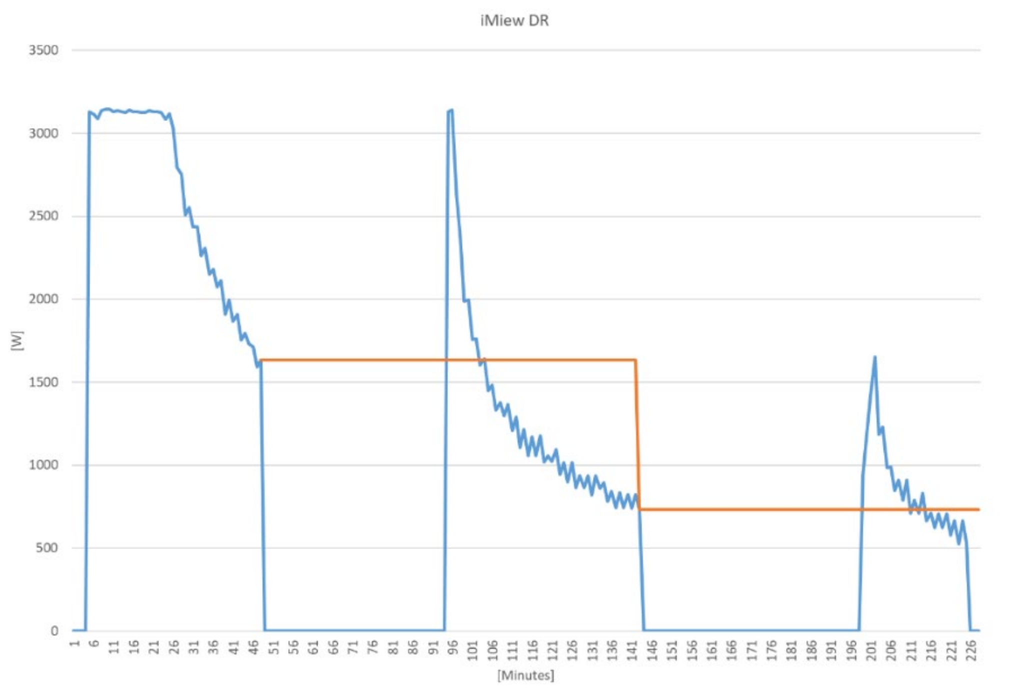
References in CINELDI:

- M.Z. Degefa, H. Sæle, I. Petersen and P. Ahcin: "Data-driven household load flexibility modelling: shiftable atomic loads", IEEE ISGT 2018
- SINTEF blog

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

Challenge and objective:

- Capacity problems in the grid due to increased peak load. Evaluate electric vehicles as a flexibility source.



Interruption periods of EV charging – during the step-down period.

Work performed:

- Analyses of 1-minutes meter data of charging profiles for different EVs and survey among Norwegian owners of EVs.

Significant results:

- 59% of households (single-family home) charge their EV at home daily.
- 49,5% of the users charge their EV at home from a normal socket (10 A).
- 90% are willing to postpone the time of charging from day/afternoon to night (hours 21-05) if this shift has no negative consequences for the user.

Impact for distribution system innovation:

- EVs are good candidates for demand response, if households are given the right incentives.

References in CINELDI:

- H. Sæle, I. Pettersen: "Electric vehicles in Norway and the potential for demand response", IEEE UPEC 2018
- SINTEF blog

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CINELDI result: Orchestrating households as collectives of participation in the distributed energy transition

Challenge and objective:

- Capacity problems in the grid due to increased peak load. Identify potential for flexibility among households.

Work performed:

- Qualitative analysis, based on interviews. Analysing orchestration of households as collectives of participation in the process of distributed energy transition.

Significant result:

- Identification of four distinct processes through which orchestration is enacted:
  1) the production of visions, expectations and imaginations, 2) network construction and re-configuration, 3) scripting and 4) domestication.

Impact for distribution system innovation:

- Increased knowledge about the potential for flexibility among households.

Reference in CINELDI:

- T.M. Skjølsvold, W. Throndsen, M. Ryghaug, I.F. Fjellså og G. Koksvik: " Orchestrating households as collectives of participation in the distributed energy transition: New empirical and conceptual insights", Energy Research & Social Science

CINELDI result: A Feasibility Study of Blockchain Technology As Local Energy Market Infrastructure

Challenge and objective:

- Increased installation of RES in distribution grid. Establish local energy market to maintain the power quality.

Work performed:

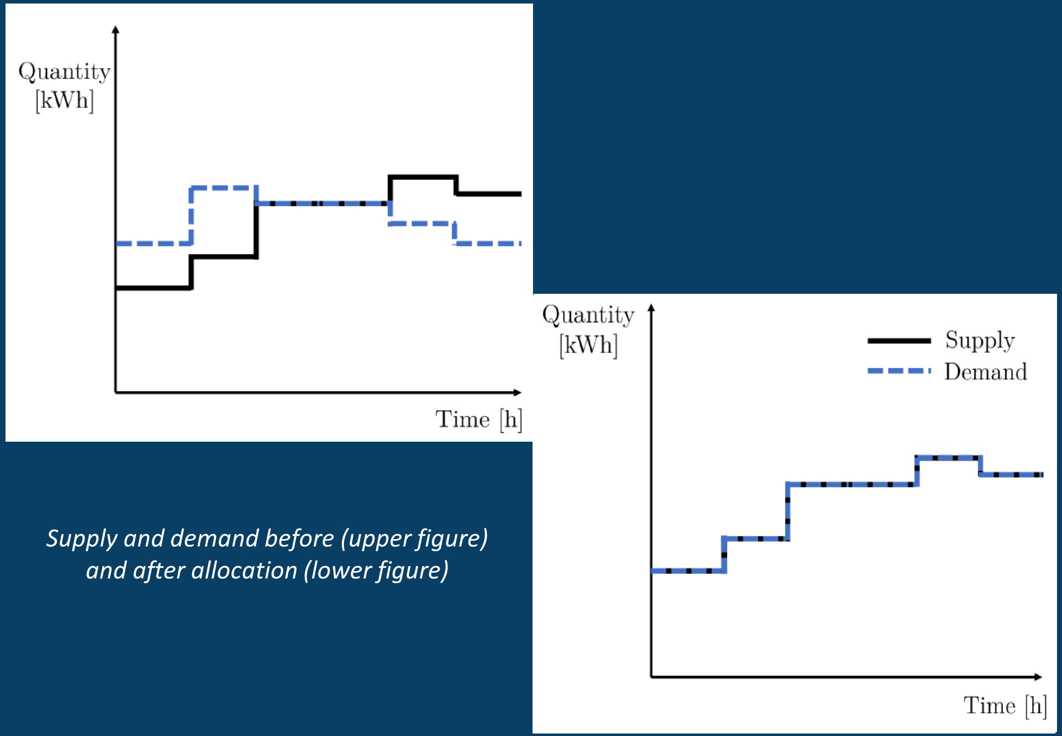
- Technical, economic and regulatory analysis with use of blockchain technology.

Significant results:

- A blockchain solution is more expensive than a database solution when it comes to development costs. A blockchain solution presents new market possibilities, which could result in a more efficient market, and hence be more economically beneficial.
- The technology behind blockchain could provide arguments for changing today's regulations, and make it possible for end users to participate actively in an energy market.

Impact for distribution system innovation:

- Increased knowledge related to use of blockchain technology for operating a local energy market.



Supply and demand before (upper figure) and after allocation (lower figure)

Reference in CINELDI:

- A master thesis "A Feasibility Study of Blockchain Technology As Local Energy Market Infrastructure", and a IEEE SEST 2019-paper

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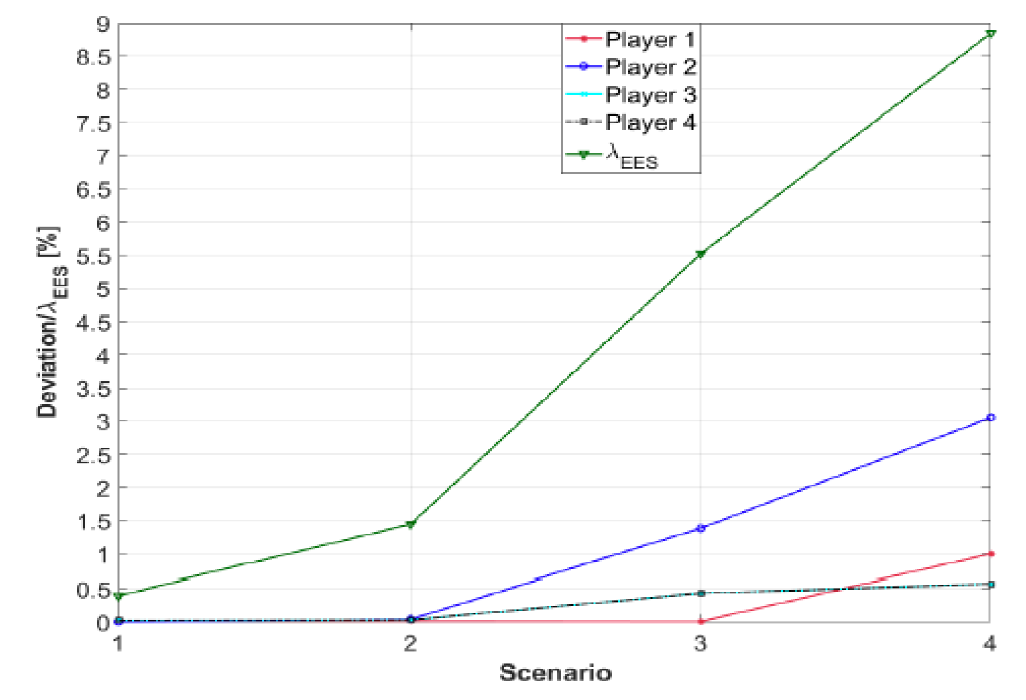
CINELDI result: Methods for Cost Allocation Among Prosumers and Consumers Using Cooperative Game Theory

Challenge and objective:

- Increased installation of RES in distribution grid. Evaluate alternative methods for allocating costs.



Relative deviation between nucleolus and Shapley for each player, along with the value of the battery system [%]

Work performed:

- Analyse two game theoretical solution concepts (nucleolus and Shapley value) for cost allocation among prosumers and consumers.

Significant results:

- Both methods provide stable cost allocations under minor deviations. Deviation between the methods increases, as the value of the battery system increases.
- The interpretation of fairness is a central issue. Results reflect that the Shapley value is based on individual contribution; thus the most active player is favored at the expense of the player with lesser resources.

Impact for distribution system innovation:

- Increased knowledge related to costs for customers with both consumption, generation and storage.

Reference in CINELDI:

- A master thesis "Methods for Cost Allocation Among Prosumers and Consumers Using Cooperative Game Theory", and a IEEE SEST 2019-paper

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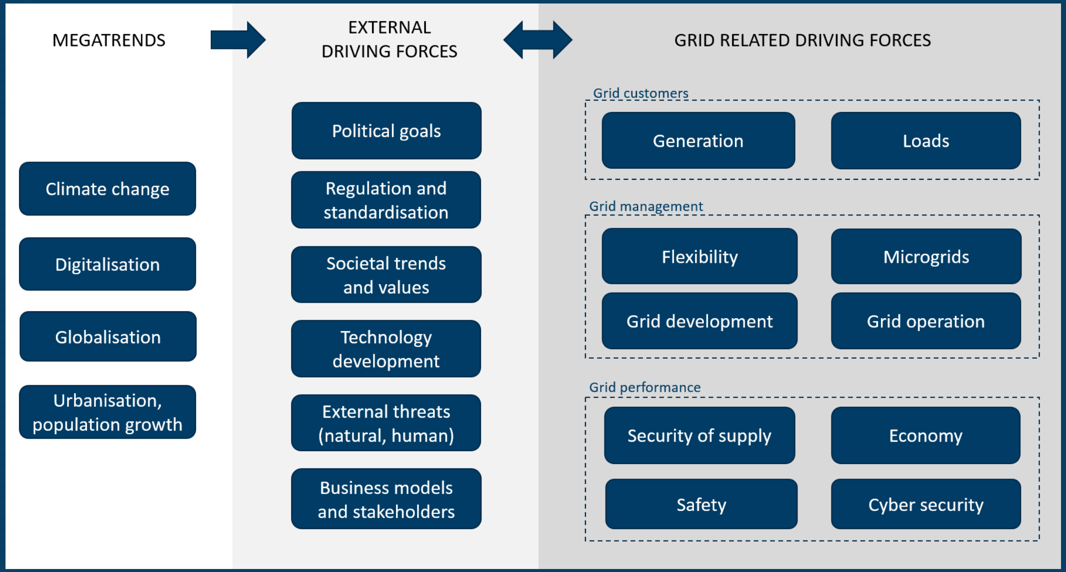
CINELDI result: Driving forces for intelligent distribution system innovation

Challenge and objective:

- The future electricity grid will be a complex system-of-systems. Identify driving forces for distribution system innovation.



Work performed:

- Drivers, barriers and enablers for distribution system innovation, for the Norwegian grid anno 2040, are identified and structured.

Significant results:

- Driving forces sorted in megatrends, external and grid related.
- Evaluated in terms of importance and uncertainty.

Impact for distribution system innovation:

- Better understanding of the complexity of the grid anno 2040 and providing a foundation for building scenarios for the future grid.

References in CINELDI:

- Report on Drivers, enablers and barriers for intelligent electricity distribution system innovation, CINELDI report 01:2019
- T.S. Hermansen, H. Vefsnmo, G. Kjølle and K. Sand: "Driving forces for intelligent distribution system innovation – results from a foresight process", CIRED 2019

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CINELDI result: Repository of mini scenarios

Challenge and objective:

- There is a need for understanding the complexity of the future Norwegian distribution system anno 2040.
- Create forward views by developing a set of credible scenarios for the electricity distribution system in Norway.

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 … the grid p…

Title: "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 … from the grid side, and possibilities for the … companies to provide flexibility / grid support in … load periods and fault situations.	
Impact on grid performance topics	
Security of supply	Batteries are utilised to increase … security of supply.
Economy	Decreased CAPEX (defer investment…
Cyber security	-
Safety	It may be challenging to know if the g… energised or not when batteries can fee… grid. This must be solved to e… personnel safety.

A mini scenario is a probable event, development or action of significance for the future electricity distribution system.

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

Work performed:

- Mini scenarios developed for the future electricity distribution grid.

Significant results:

- 109 mini scenarios are developed and collected in a repository.
- Examples of possible impact on the grid performance.

Impact for distribution system innovation:

- Better understanding of the complexity of the grid anno 2040. Mini scenarios are input to building scenarios for the future grid, and for further research, strategies and competence building.

References in CINELDI:

- Blogs: "Smart grid scenarios" and "Utvikle scenarier for fremtidens distribusjonsnett"
- T.S. Hermansen, H. Vefsnmo, G. Kjølle and K. Sand: "Driving forces for intelligent distribution system innovation – results from a foresight process", CIRED 2019

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