CINELDI

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

Norwegian Centre for
Environment-friendly
Energy Research

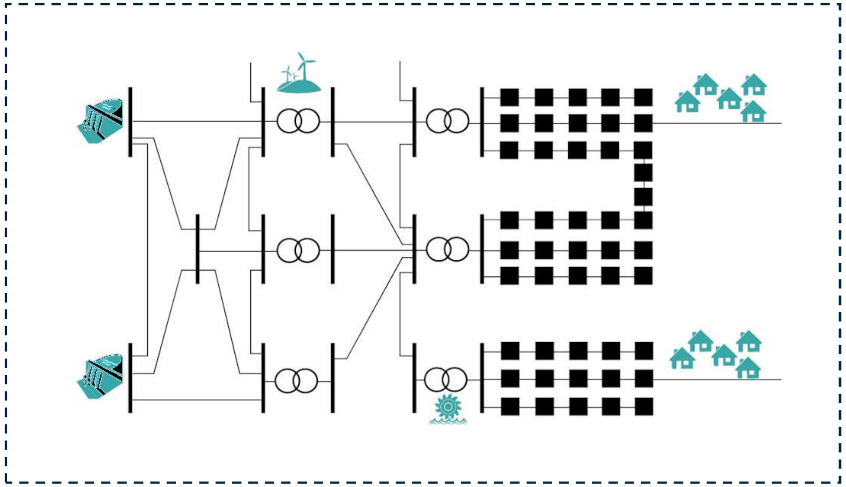
Fremtidens nettdrift - testing i smartgridlab av ny funksjonalitet med smarte målere

Trondheim, 6. november 2024

Hermund Slaatsveen, Henning Taxt

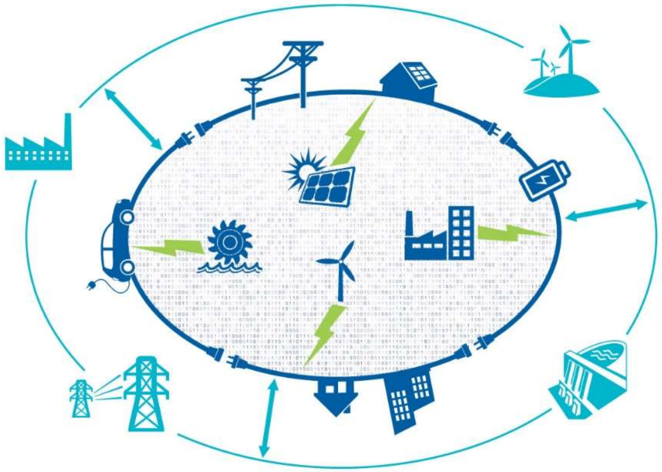
Store endringer – nye behov i nettdriften

Dagens kraftsystem



Effektflyt

Fremtidens kraftsystem



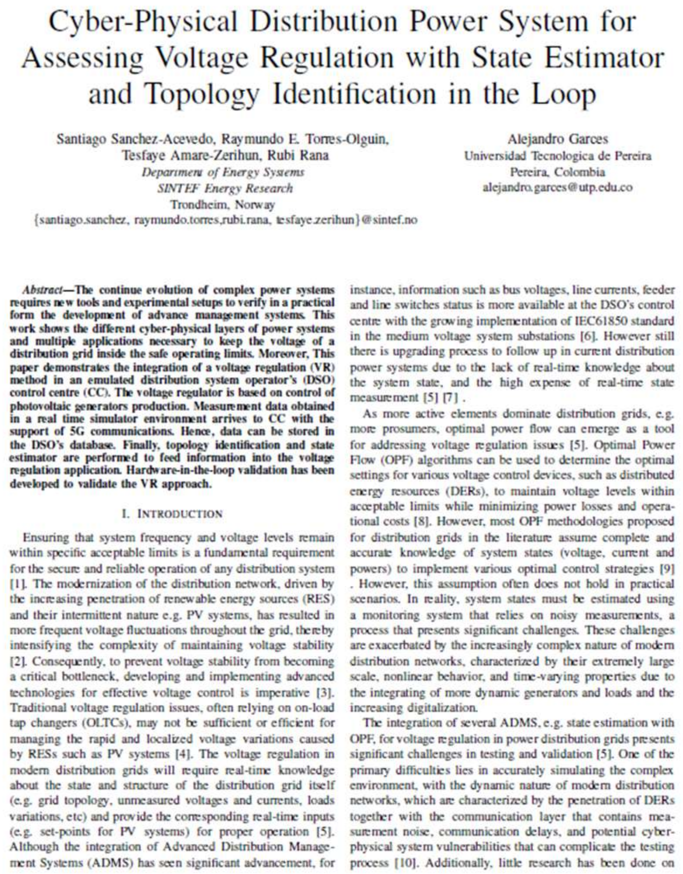
Effektflyt

National Smartgrid Laboratory (NSGL)

- Driftet av NTNU og SINTEF
- Fleksibelt og kontrollerbart miljø for forskning og utvikling innen smartgrid-teknologi
- Kapabilitet for testing av hard-ware, styringsalgoritmer og kommunikasjon

CINELDI

Cyber-fysisk test-oppsett



Cyber-Physical Distribution Power System for Assessing Voltage Regulation with State Estimator and Topology Identification in the Loop

Santiago Sanchez-Acevedo, Raymundo E. Torres-Olguin, Tesfaye Amare-Zerihun, Rubi Rana
Department of Energy Systems
SINTEF Energy Research
Trondheim, Norway
{santiago.sanchez, raymundo.torres,rubi.rana, tesfaye.zerihun}@sintef.no

Alejandro Garces
Universidad Tecnologica de Pereira
Pereira, Colombia
alejandro.garces@utp.edu.co

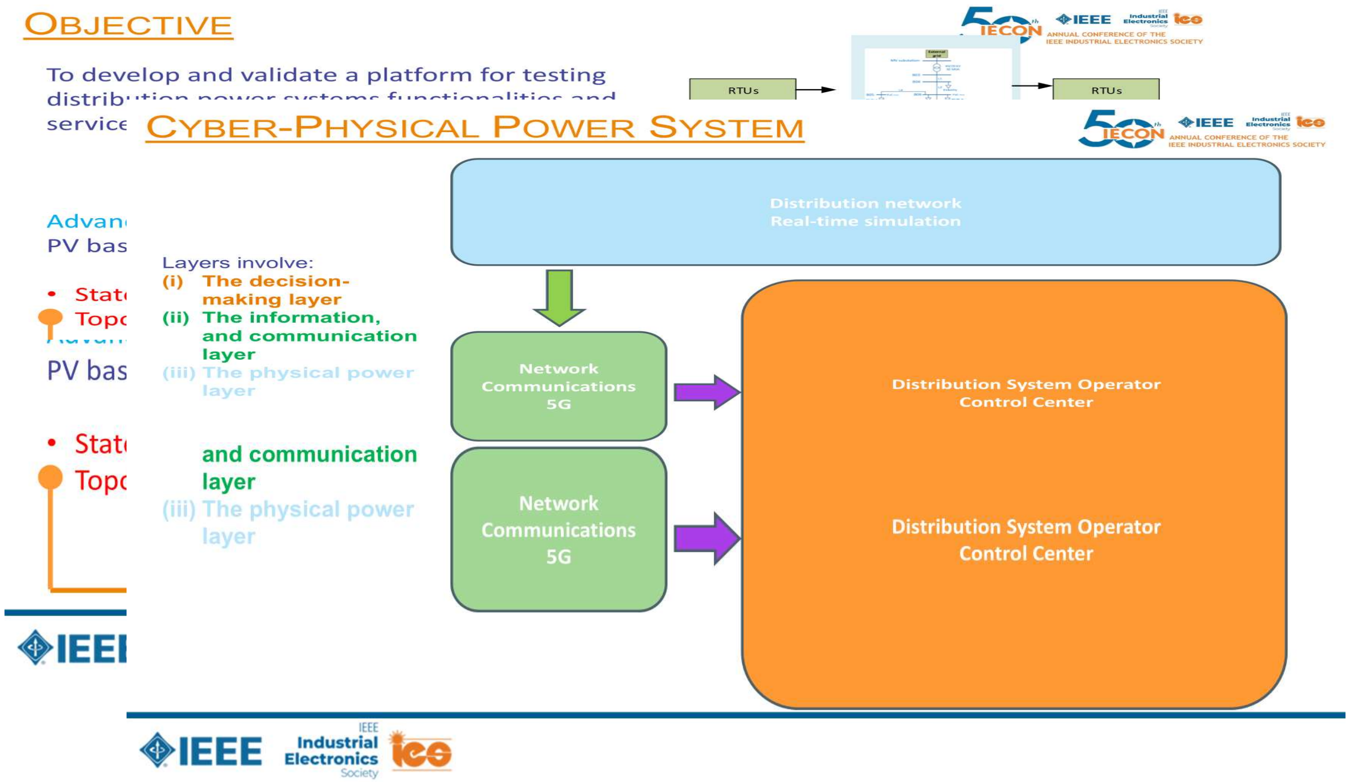
***Abstract*—The continue evolution of complex power systems requires new tools and experimental setups to verify in a practical form the development of advance management systems. This work shows the different cyber-physical layers of power systems and multiple applications necessary to keep the voltage of a distribution grid inside the safe operating limits. Moreover, This paper demonstrates the integration of a voltage regulation (VR) method in an emulated distribution system operator's (DSO) control centre (CC). The voltage regulator is based on control of photovoltaic generators production. Measurement data obtained in a real time simulator environment arrives to CC with the support of 5G communications. Hence, data can be stored in the DSO's database. Finally, topology identification and state estimator are performed to feed information into the voltage regulation application. Hardware-in-the-loop validation has been developed to validate the VR approach.**

I. Introduction

Ensuring that system frequency and voltage levels remain within specific acceptable limits is a fundamental requirement for the secure and reliable operation of any distribution system [1]. The modernization of the distribution network, driven by the increasing penetration of renewable energy sources (RES) and their intermittent nature e.g. PV systems, has resulted in more frequent voltage fluctuations throughout the grid, thereby intensifying the complexity of maintaining voltage stability [2]. Consequently, to prevent voltage stability from becoming a critical bottleneck, developing and implementing advanced technologies for effective voltage control is imperative [3]. Traditional voltage regulation issues, often relying on on-load tap changers (OLTCs), may not be sufficient or efficient for managing the rapid and localized voltage variations caused by RESs such as PV systems [4]. The voltage regulation in modern distribution grids will require real-time knowledge about the state and structure of the distribution grid itself (e.g. grid topology, unmeasured voltages and currents, loads variations, etc) and provide the corresponding real-time inputs (e.g. set-points for PV systems) for proper operation [5]. Although the integration of Advanced Distribution Management Systems (ADMS) has seen significant advancement, for instance, information such as bus voltages, line currents, feeder and line switches status is more available at the DSO's control centre with the growing implementation of IEC61850 standard in the medium voltage system substations [6]. However still there is upgrading process to follow up in current distribution power systems due to the lack of real-time knowledge about the system state, and the high expense of real-time state measurement [5] [7] .

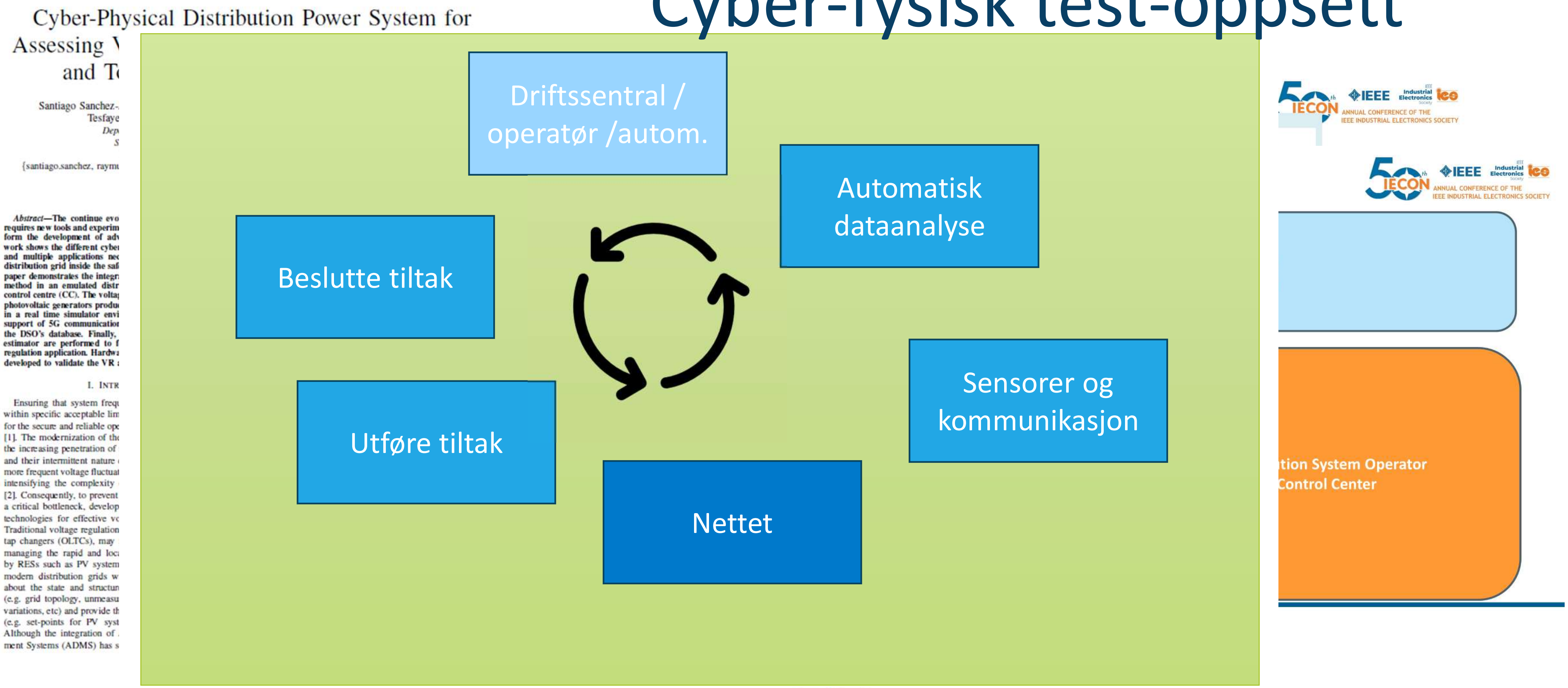
As more active elements dominate distribution grids, e.g. more prosumers, optimal power flow can emerge as a tool for addressing voltage regulation issues [5]. Optimal Power Flow (OPF) algorithms can be used to determine the optimal settings for various voltage control devices, such as distributed energy resources (DERs), to maintain voltage levels within acceptable limits while minimizing power losses and operational costs [8]. However, most OPF methodologies proposed for distribution grids in the literature assume complete and accurate knowledge of system states (voltage, current and powers) to implement various optimal control strategies [9] . However, this assumption often does not hold in practical scenarios. In reality, system states must be estimated using a monitoring system that relies on noisy measurements, a process that presents significant challenges. These challenges are exacerbated by the increasingly complex nature of modern distribution networks, characterized by their extremely large scale, nonlinear behavior, and time-varying properties due to the integrating of more dynamic generators and loads and the increasing digitalization.

The integration of several ADMS, e.g. state estimation with OPF, for voltage regulation in power distribution grids presents significant challenges in testing and validation [5]. One of the primary difficulties lies in accurately simulating the complex environment, with the dynamic nature of modern distribution networks, which are characterized by the penetration of DERs together with the communication layer that contains measurement noise, communication delays, and potential cyber-physical system vulnerabilities that can complicate the testing process [10]. Additionally, little research has been done on



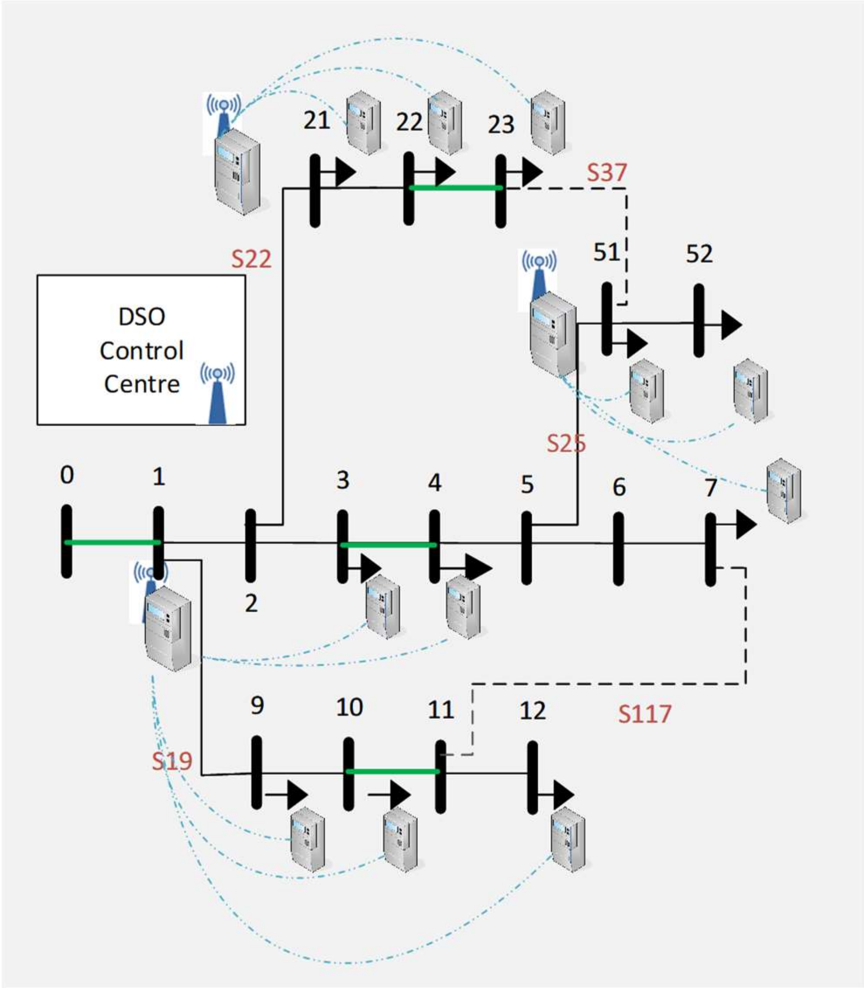
CINELDI

Cyber-fysisk test-oppsett



Framtidens nettdrift - datakilder

- AMS gir tilgang til målinger av strøm og spenning i alle målepunkt
- Denne informasjonen kan brukes til:
  - Bestemme nettbildet
  - Oppdage avvik
  - Estimere flyten i hele nettet
    - Det vil si, sette sammen data fra SCADA og AMS
  - Flyten må formuleres konsistent for å automatisere



CINELDI

CINELDI sluttkonferanse

Samarbeid gir resultater! Et eksempel.

Makes sense.

Aidon
a gridspertise company

Økt nytteverdi av AMS leveransene i det norske markedet

Ledende leverandør av AMS målere i det norske markedet

Case: Analysere jordfeil og automatisere feilretting.

Men det var noen utfordringer:

- Jordfeil i IT nett er et særnorsk fenomen!
- Testing krevde ekspertise i teori og praksis hvordan IT-nettverket fungerer!

CINELDI

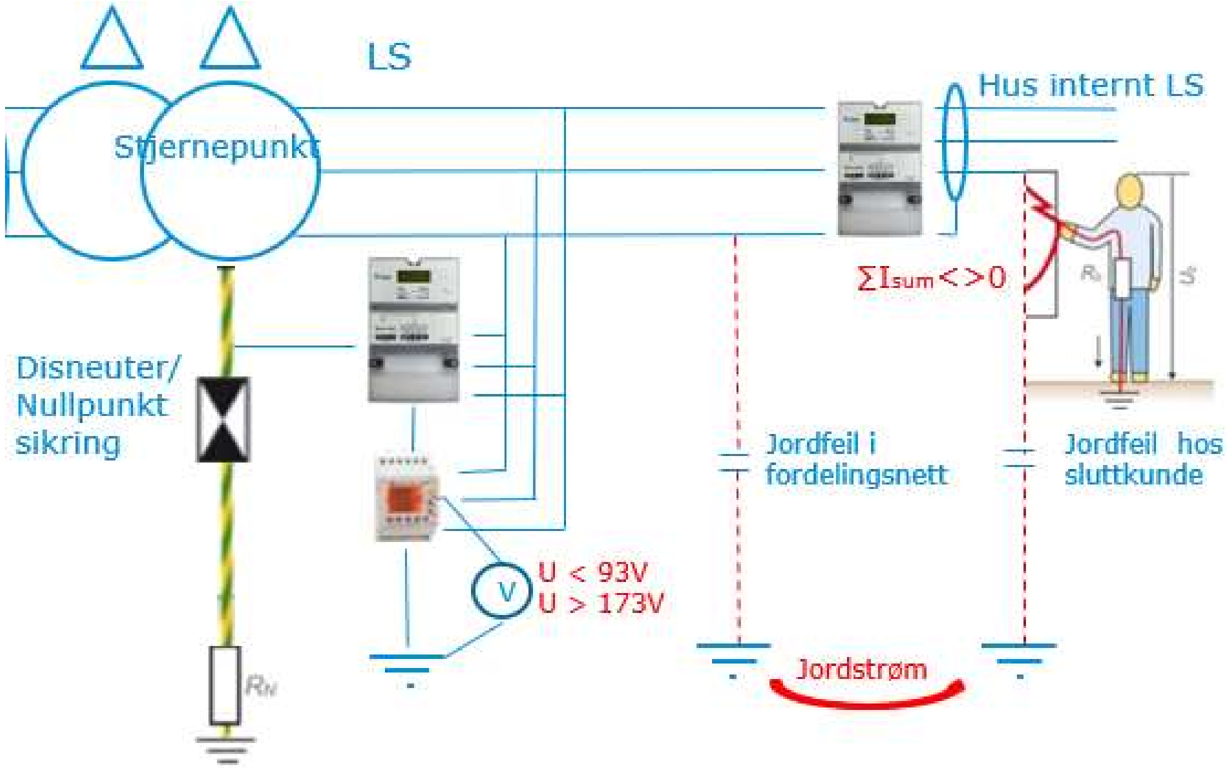
Slide 8

HS0 Illustration of A market leader
Hermund Slaatsveen, 2024-10-31T12:02:11.335

HS1 Illustration of A challange
Hermund Slaatsveen, 2024-10-31T12:04:34.744

Aidon
a gridspertise company

Jordfeil i IT nett - Et særnorskt fenomen!



CINELDI

Aidon
a gridspertise company

Innovasjonen: Avansert jordfeilsdeteksjon i IT nett

CINELDI/Smartgrid lab tilbød et utmerket sted å ha testingen:

- Velprøvd nettverkssimuleringsevne for å lage IT-nettverksmiljø for testing
- Mulighet for å gjøre variasjoner i nettverk og simulere typiske situasjoner i det virkelige liv
- Mulig å gjøre trinnvise endringer i ulike variabler

Ekspertisen på høyt nivå bidro til at vi fikk et godt datagrunnlag for å utvikle løsningen.

CINELDI

Slide 10

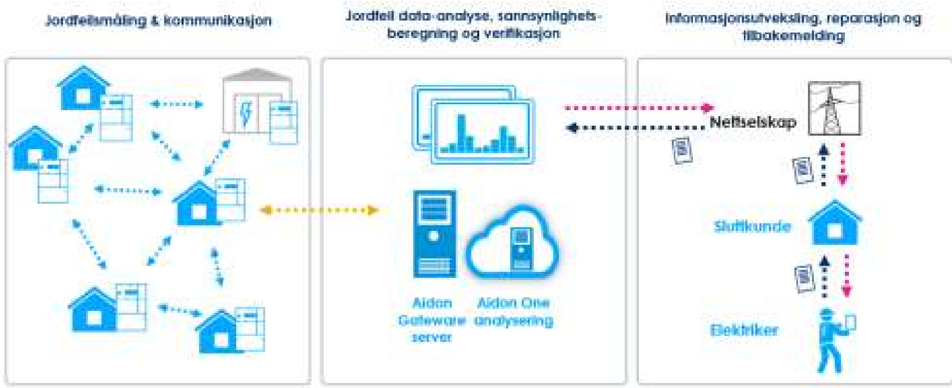
HS0 Illustration of Testing

Hermund Slaatsveen, 2024-10-31T12:08:56.511

Aidon
a gridspertise company

Resultatet: Automatisert jordfeilshåndtering

- Automatisert feilrettingsprosess og kommunikasjon med kunde
- Analyseverktøy for diffuse feil
- Styring av prosessen



CINELDI

Aidon
a gridspertise company

Suksessfaktorer ved deltakelse i en FME som CINELDI

- Forstå fremtidstrender og senarioer
- Øke innovasjonsevnen
- Utvikle rett ting til rett tid
- Redusere risiko i utviklingen
- Få tilgang til Smart Grid miljøer, reelle nettdata, og Smart Grid laboratorier
- Tilføre verdi til levert AMS plattform over levetiden
- Øke investeringsavkastningen på AMS investeringen for våre kunder og oss selv
- Publisitet rundt resultatene
- Skape konkrete resultater i samarbeid med nettselskap, akademia og industrielle aktører

CINELDI

Aidon
a gridspertise company

Hvilke erfaringer har vi gjort oss?

- Grundig fremtidsscenario definisjoner er viktig!
- Usecase metodikk fungerer meget bra.
- Sammensatte løsninger krever godt samspill mellom flere fagmiljøer
- Åpen innovasjon kan være en utfordring for kommersielle aktører!

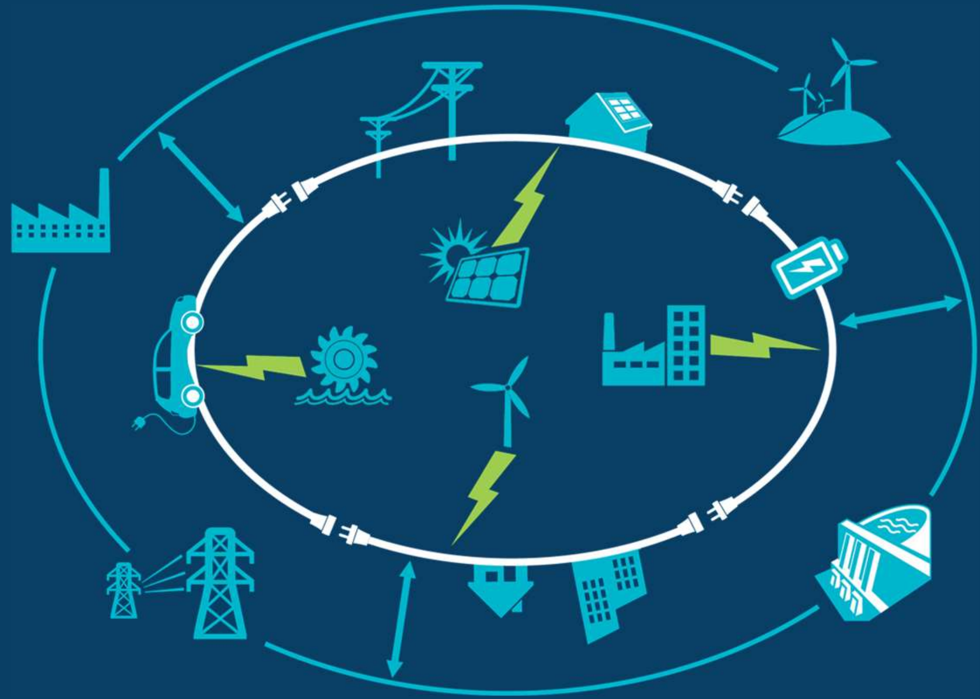
CINELDI

Samarbeid gir resultater!

CINELDI

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

Norwegian Centre for
Environment-friendly
Energy Research



This work is funded by CINELDI - Centre for intelligent electricity distribution, an 8 year Research Centre under the FME-scheme (Centre for Environment-friendly Energy Research, 257626/E20). The authors gratefully acknowledge the financial support from the Research Council of Norway and the CINELDI partners.

cineldi.no CINELDI_FME blog.sintef.com/ linkedin.com/company/cineldi/