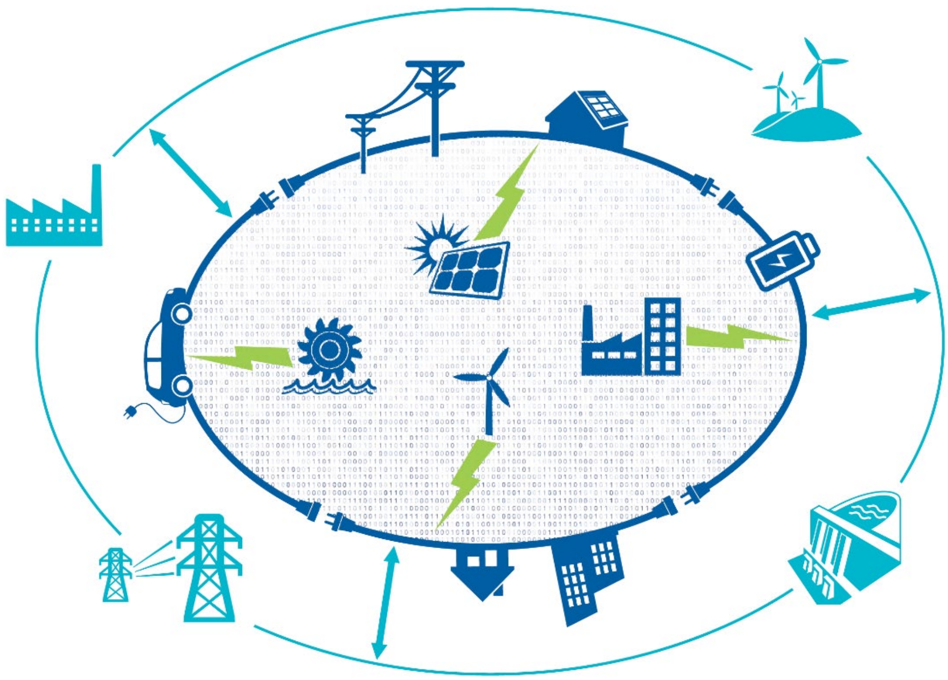
Pilot sluttrapport: Smart Cable Guard

Forfatter: Robert Seguin, Elvia



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Prosjektnotat

TITTEL			
Resultat og erfaringsnotat for pilot *Smart Cable Guard*			
WORK PACKAGE	**VERSJON**	**DATO**	**ANTALL SIDER**
WP Pilot	1.1	2021-05-21	12
FORFATTER(E)		**WP-LEDER**	**GRADERING**
Robert Seguin		Maren Istad	CINELDI Intern

DISTRIBUSJON		

SAMMENDRAG

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Innholdsfortegnelse

1 Bakgrunnsinformasjon

Tabell 1 Bakgrunnsinformasjon

	Gjeldende bakgrunnsinformasjon	**Viktige endringer i løpet av pilotperioden**
Målsetting	This pilot project will test a technology that can detect partial discharges in MV cables – Smart Cable Guard™ (SCG). The technology has to main use cases: 1. Operation: Detection and localization of faults → reduction of outage time. 2. Gird planning / maintenance: Condition monitoring of the cables. This will potentially enable better re-investment strategies for managing the existing cable inventory. The main goal is testing and verification of the technology in Elvia's cable network on both paper insulated cables and XLPE cables.	
Problemstilling	The cable network in the Oslo area consists of a number of older cables. Many of them are old paper insulated cables. However, no online monitoring of these cables is established in the field. The cables are therefore replaced on a pure operate-to-fail basis. Partial discharges (PD) are an indicator for weak spots on the cables or cable interconnections. There is a measurement system available at HN based on the *VLF tan delta* diagnostic method. This system, however, only works on XLPE cables and only under offline conditions. This last point is the main reason why the system is rarely used. Smart Cable Guard ™ (SCG) is an alternative technology for the detection of PDs based on detecting high-frequency electric pulses caused by the discharge. Its two main advantaged over the existing system are a) that it can be used on cables in service– meaning that it can be used for online monitoring of the cable and b) that it is independent of the cable type; it can therefore also monitor older paper insulated cables that are more prone to failure. The analysis of PD signals is far from trivial. While the interpretation of the *VLF tan delta*	

	measurements is established through an interpretation guideline from SINTEF and from international standards (i.e. IEEE 400.2-2013) the analysis of the SCG data is proprietary to the system provider DNV-GL . One fundamental difference of the PD behavior in the two different cable types is that PD in XLPE cables leads to short-term failure of the cable. Paper insulated cables tend to show more dynamic PD signatures. This demonstration project wishes to test the SCG system on both XLPE and paper insulated cables on strategic connections in HN's cable network. It will open up the possibility of a more sophisticated operation strategy. For paper insulated cables it will quantify the risk of failure, i.e. give an indication for the cable's remaining lifetime. In XLPE cables we will test if a warning system can be established that is dynamic enough to disconnect the cable in a controlled way before an unplanned outage occurs.	
Aktiviteter	**1. Installation of measurement system** Establish SCG system and communication to detect partial discharges on 11/22 kV cables. 6 test locations will be selected, 3 with XLPE cables and 3 with paper insulated cables. **2. Data collection and analysis paper** Collection of PD data on paper insulated cables. Interpretation and verification of the data in the field. Development of a preliminary action plan. **3. Data collection and analysis PEX** Collection of PD data on PEX cables. Offline comparison of the data with results from the existing *VLF tan delta* measurement system. Establishment of a process that is fast enough to avoid unplanned outages.	The system has been moved to different locations to test both the relocation process and different cable segments.
Kostnadsestimat	6 systems are installed in Elvia's network Investment: 5 500 EUR per system Operating fee: 800 EUR per system per year Mobil data fee for 2 SIM-cards per system (1 per system).	

Innovasjonspotensial	Use case 1: More effective fault handling process. The fault location should be known within minutes after the fault. No test switching necessary in order to isolate the fault. User: control room, fault recovery team. Use case 2: More advanced asset management based on condition monitoring and not purely operate-to-fail. User: Maintenance, grid planning. Matureness: The product is commercially, but the functions are still under constant improvement and development. The technology had not been tested in Norway before.	
Forventet resultat	- Fault statistics - Improved fault handling process - Implementation of condition monitoring on cables. - Business case - Recommendation	
Tidsplan	Initial placement analysis and installation period. Data collection over almost three years (2018 – 2021)	The collection period has been extended several times, due to the low number of faults.

2 Om piloten og fysisk pilotområde

Tabell 2 Piloten og pilotområdet

Pilotområdet	6 cables / cable sections in Elvias medium voltage cable grid in Oslo (11 kV). Feeders selected according to: - Historically experienced problems or challenges - Cable sections with many joints - Different cable types - Cable sections that have a mix of cable types between joints The length of the monitored segments is between 1 and 5 km.
Måledata og andre data som samles inn og lagres fra piloten	PD-data are accessible only via the DNV-GL web interface.
Personvern og/eller kraftsensitiv informasjon	Actual feeders and secondary substations where the systems are installed were not disclosed due to “beredskapsforskriften”.

Måle- og kommunikasjonsinfrastruktur	Only SCG-hardware: PD-sensor, communication system to collect sensor data and send them via 4G to DNV
Use case beskrivelser og testplaner	Use case 1: More effective fault handling process. The fault location should be known within minutes after the fault. No test switching necessary in order to isolate the fault. User: control room, fault recovery team. Use case 2: More advanced asset management based on condition monitoring and not purely operate-to-fail. User: Maintenance, grid planning.
Regulering og forskrifter	n/a
Barrierer og løsninger	Data communication of the new data to the control room. Integration into SCADA was discussed but not done in the project period. Temporary solution via email and SMS.
Hvem skal eventuelt ta resultater fra piloten i bruk?	Control room will take over the systems since only use case 1 gave relevant results (see chapter 3).
Informasjonsdeling mellom aktørene – før – underveis – etterpå	Regular technical meetings between Elvia and DNV-GL, especially during the first phase of the project. Regular presentations of results in CINELDI-meetings. No communication to customers necessary.
Er det laget planer for videreføring – skalering – fullskala implementering?	Based on the economic analysis ("business case") Elvia decided to not scale up. The costs were greater than the observed savings, given the current KILE-ordning and fault frequency (based on historic fault statistics). The existing systems, however, will not be taken down, but will continue to monitor the current cable segments.

3 Resultater og innovasjoner fra piloten

3.1 Generelle resultater

During the project period, SCG indicated five faults (use case 1). Three of them were actual faults, two were planned switching operations due to maintenance work in the underlying, low-voltage distribution grid.

The three fault sources were:
- Punctured cable
- Damaged cable due to construction works
- Unknown fault type, cable was under a building. A new cable segment was installed as replacement and the faulty cable segment was not extracted.

The precision of the indicated fault location was within the 1% that has been promised by the manufacturer. The precision is limited by the data quality in Elvia's cable database and. Different cable types result in slightly different signal speeds, which affects the indicated location.

There were **no recorded cases for identification of weak spots** before an actual fault (use case 2).

After the initial successful demonstration of the technology during the first fault, the system was integrated in the operations process flow for fault location and restoration by

- Making fault information automatically available for operations via automatically sent SMS and email.
- Indicating locations of the SCG-sensors into the grid information schemes (enlinjeskjema).

It is not straightforward to define the **TRL-level**. Since the technology is commercially available it is 8-9 on technology level. On system integrations level it is more 6-7. Full integration into SCADA has not taken place yet.

No **lifetimes analyses** have been conducted. All systems are still operational after three years. Expected life time (used in the business case calculations): 10 years.

Scalability:Technically the system can be used on all MV-cables. However, there are a number of parameters that restrict the applicability and especially the economic viability:

- physical access to the grounding cables
- degree of branching of the grid
- length of the cables
- other installed sensor systems
- installed remotely controlled switches

Since only use case 1 could be confirmed during the test period, the economic viability of the system is not given as of today. This could change with

- Higher costs for faults (KILE-ordning)
- Unusually high costs for re-investment of specific cables.
- Confirmed use case 2 (condition monitoring)
- Other use cases that give value: The system can collect other data, e.g. noise patterns depending on load situation in the grid, signal speed depending on cable temperature. There are ongoing activities at DNV that aim at establishing such added value.
- Lower investment and service cost.

3.2 Konkrete innovasjoner

Tabell 3 Forskningsrådets innovasjoneskategorier

Type Innovasjon	Antall
Ferdigstilte nye/bedre metoder/modeller/ prototyper	
Bedrifter **utenfor** FMEen som har innført nye/forbedrede metoder eller modeller eller teknologi	
Bedrifter **innenfor** FMEen som har innført nye/forbedrede arbeidsprosesser	
Bedrifter **innenfor** FMEen som har innført nye/ forbedrede metoder eller modeller eller teknologi	
Inngåtte lisensieringskontrakter	
Registrerte patenter	
Ferdigstilte nye/forbedrede produkter	
Ferdigstilte nye/forbedrede prosesser	1
Ferdigstilte nye/forbedrede tjenester	
Nye foretak som følge av FME'en	
Nye forretningsområder i eksisterende bedrifter	

New process 1: Integrated information from SCG-system about fault locations into the fault restoration process of the operations team (without the R&D team having to be involved). This extra information leads to reduced outage time due to more precise switching operations and helps the repair crew with the fault localization.

4 Tekniske/faglige erfaringer fra piloten

Tabell 4 Tekniske/faglige forhold

Tekniske forhold	Positive erfaringer	Negative erfaringer
Hardware/utstyr	Easy to install and move	
Software	Easy to use web interface	Missing open API's, only proprietary solution
Kommunikasjon		Depends on 4G signal, that can be a challenge in transformer stations. Proprietary solution hard to integrate into SCADA.
Funksjonalitet	High precision	

Brukervennlighet/ kompetanse som kreves	Needs on-site support for the first instalment. Then good remote support.	
Service/oppfølging/feilretting	Good support	
Interoperabilitet		
Barrierer		High costs.
Suksessfaktorer		
Ytelse (leverte utstyret som forventet – hva med tidsresponser)		
Fysiske effekter på kraftsystemet (spenningsforhold, kortslutningsytelse, avbruddsforhold osv.)		
Service, oppfølging og feilretting fra leverandører av utstyr	Good support.	
Tekniske anbefalinger/læring/teknisk risiko		
Annet		

Oppsummering

1. System er lett å installere og kan, hvis jordingskablene er tilgjengelige til og med installeres med strømmen på.
2. Feil lokalisering funker veldig bra. Nøyaktighet er under 1 % og mest påvirket av dårlig datakvalitet i kabeldatabasen.
3. Ingen varsler på svake punkt under hele prosjektperioden. Funker det i det hele tatt? Uflaks? Fungerer i Nederland, men antall systemer muligens ikke stort nok

5 Kost/nytte

The analysis below clearly shows that under today's circumstances (regulation, fault statistics) the system is too expensive to provide a positive business case. It would be feasible only under very specific conditions (e.g. critical cables with high KILE and high specific re-investment costs).

As mentioned in chapter 3 under "scalability" an number of parameters could influence the economic feasibility.

It is worth noting that 0-alternative in the analysis below is a grid without sensors or possibility for remotely controlled switching, i.e. the lowest possible degree of monitoring and control. Any introduction of such devices will reduce the value of the single monitoring system. In that case a more holistic analysis has to be conducted to find out the optimal number and type of sensors / RTUs.

Noen tall

… **om installerte systemene og registrerte feil**

- 3 feil på tre år på 18 km kabel → 5,6 feil per 100 km per år
- KILE per feil: 220 kkr
- 50% reduksjon i feilrettingstid. Grov antagelse basert på første feilen, hvor vanlig prosedyre ble fulgt og SCG ignorert.

… **om Elvia Sør sitt kabelnett**

- 8735 km HS-kabel; 185 feil / år → 2,1 feil per 100 km per år
- 114 kkr KILE per feil i gjennomsnitt

Hafslund Nett

Case 1: Nyinvestering, gjennomsnittlig KILE

- 1 EUR = 10 NOK
- Invest per system = 5 500 EUR, antatt levetid 10 år
- Abonnement = 800 EUR
- Kostnader mobilabonnement = 2 400 NOK
- Antall feil per 100 km per år = 5,6
- KILE per feil = 114 kkr

- Kostnad* = 15 900 NOK pr år pr system
- Besparelse = 9 600 NOK pr år pr system

* Invest + serviceabo fra DNV + mobilabo

Hafslund Nett

Case 2: Invest tatt på FoU, gjennomsnittlig KILE

- 1 EUR = 10 NOK
- Invest per system = **0 EUR**
- Abonnement = 800 EUR
- Kostnader mobilabonnement = 2 400 NOK
- Antall feil per 100 km per år = 5,6
- KILE per feil = 114 kkr

- Kostnad = **10 400 NOK** pr år pr system
- Besparelse = 9600 NOK pr år pr system

Hafslund Nett

Case 3: Invest tatt på FoU, høy KILE

- 1 EUR = 10 NOK
- Invest per system = **0 EUR**
- Abonnement = 800 EUR
- Kostnader mobilabonnement = 2 400 NOK
- Antall feil per 100 km per år = 5,6
- KILE per feil = **220 kkr**

- Kostnad = **10 400 NOK** pr år pr system
- Besparelse = **18 500 NOK** pr år pr system

20 Hafslund Nett

Business case

	Verdi per system per år
CASE 1 (Nyinvestering, normal KILE)	**- 6 300 NOK**
CASE 2 (Invest på FoU, normal KILE)	**- 800 NOK**
CASE 3 (Invest på FoU, høy KILE)	**+ 8100 NOK**

21 Hafslund Nett

The result demonstrates the negative business case under today's circumstances (CASE 1). However, a future reduction of cost (CASE 2) or increased value (CASE 3, here assumed doubling of KILE with respect to average KILE per cable fault) also show that it is not unrealistic to reach profitability. Alliander, the biggest DSO in the Netherlands, has installed more than 1000 systems already, stating that the system is profitable under the given circumstances in their operating area.

6 Anbefalinger og videre arbeid

1. Roll-out of the system, i.e. invest into more systems, is not feasible today. Especially the service fee per system is too high.
2. The reason why we did not see any indications for weak spots in the cables was much discussed in the project. It could just be bad luck due to the low number of tested systems. Without the value due to condition monitoring (use case 2) the system is too expensive.
3. The existing systems will be transferred from R&D to operations.
4. Additional use cases have been discussed in the project. Here are further possibilities for R&D:
    a. Which value lies in the data about signal speed (→ cable temperature, possibly dynamic line rating)?
    b. What can be learned from the specific noise patterns that can be observed about the general conditions in the grid? Which type of loads produce such patterns?

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