# NO SMART MV/LV STATION WITHOUT A SMART APPROACH

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## *ABSTRACT*

*At the end of 2014, at several different locations in the Netherlands, pilot systems for automated substations were installed. These pilot systems are the result of the final phase of the KRIS project, an initiative of multiple Distribution System Operators (DSOs) in the Netherlands, which started in 2012. What makes the KRIS Project unique is that these DSOs worked closely together to establish a list of common functional requirements. Then the suppliers brought in their experience and knowledge regarding the technical feasibility and cost aspect of those requirements.*

*For engineering the V-model was used. During the specification phase all parties worked together, sharing information with a cooperative mentality.*

*Throughout the pilot phase suppliers, forming coalitions, were challenged to work on their own solution. The goal of the project was to come up with a cost effective instrumentation of MV/LV equipment. Facing the end of the project, the results show a competitive TCO for instrumentation used in so-called strategic MV/LV stations. For non-strategic stations the TCO does not yet meet the expectations. This paper is written by coalition ERE, one of the coalitions formed by Eleq, Reewoud Energietechniek and Eaton Industries.*

## INTRODUCTION

Starting in 2012 multiple Distribution System Operators (DSOs) in the Netherlands recognized that the energy transition requires management of all elements in the energy network. Therefore intelligent components will be required on all secondary distribution levels, especially in the MV/LV substations, the so called Ring Main Units (RMUs).

Due to the high costs of such instrumentation, a large scale roll-out was financially not feasible.

In addition, the suppliers were not aware of the DSOs requirements for these components. The result: no match between DSOs demands and the suppliers' solutions.

To break this deadlock, project KRIS was initiated by the DSOs. The goal of KRIS is defined as to create an open innovative and competitive instrumentation market aiming at low cost and modular MV/LV instrumentation, by stimulating close cooperation between demand and supply chains.

## ORGANISATION KRIS PROJECT

The participants in the KRIS project, as shown in Figure 1, can be grouped in DSOs and Suppliers, supported by Avans, an academic Educational Institute and Technolution, a technology partner specialized in enabling the interpretative step from business to the right technological solution.

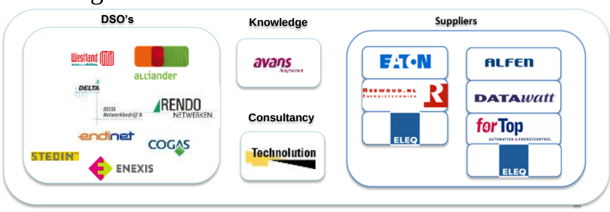


*Figure 1: Participants of the KRIS project*

The project is structured as follows:

- steering committee, formed of representatives of all parties
- users group, formed by the DSOs
- suppliers group, working together in coalitions

The steering committee acts as the decision-making platform, has periodical meetings and informs the users group about the progress of the project.

## PROJECT PHASING

To reach the goal of the project, come to a cost effective instrumentation of MV/LV equipment, a structured approach for product development, as shown in Figure 2, was followed.

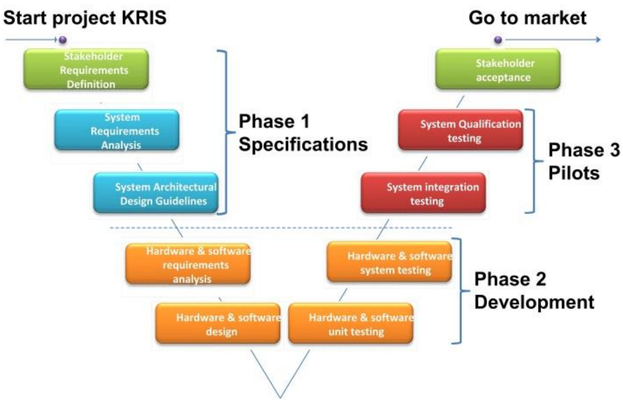


*Figure 2: Systems Engineering V-model*

## Phase 1 – Specifications

In Phase 1, plenary meetings with all participants were held to build the concept for the specifications document. With the outcome of these sessions, the Operational Concept Description (OCD) [1] was set up. This was the start document and describes all global requirements. From this, the System/Sub system Specification (SSS) [2] was written. This document specifies the requirements for a system or subsystem and the methods to be used.

To fill in all the details of the specifications a number of Working Groups (WGs) were formed, with specialists from both the DSOs and the suppliers. Each Working Group had its own specialized tasks.

- *WG Use Cases*
  - Describe the use cases for MV/LV substations.
  - Prioritize the described functionalities according to the needs of all DSOs.
- *WG Security*
  - Describe the security demands.
  - Investigate available information and requirements.
- *WG Key Figures*
  - Investigate the installed base of MV/LS stations in the Netherlands in terms of total units, configuration settings, and plans for replacement and/or retrofit.
- *WG Environment*
  - Create an overview of existing projects and developments in the field of instrumentation MV/LV stations.
  - What are the lessons learned, what should we take into account?
- *WG Measurements*
  - Specify the technical requirements underlying the measurements needed to realize the use cases.
- *WG Installation and Maintenance*
  - Investigate the minimum system requirements in terms of safety, legalisation, standards, climate, environment, accessibility, electricity and mechanics.
  - Describe a typical MV/LV installation.
- *WG Data Communication*
  - Investigate the needs for Data Communication.
  - Set up a long list with possible Data Communication Protocols.
- *WG Architecture*
  - Describe the preferred system architecture in terms of structure, behaviour, modularity and interfaces, both for hardware and software.
- *WG Total Cost of Ownership (TCO)*
  - Develop a tool to validate the costs of acquisition, installation and maintenance, taking into consideration the entire life time of the system.
- *WG Pilots & Test fields*
  - Coordinate the implementation and instalment at the test field locations of the designed systems.

## Phase 2 – Development

In Phase 2, the suppliers formed coalitions to develop a modular system designed to meet the requirements stated in the OCD [1] and SSS [2]. Each coalition came up with its own product. One of the requirements was that the instrumentation should be added to existing MV/LV systems. Therefore it was very important to have a flexible solution, with open interfaces to its surrounding. After testing the developed systems in the laboratory of one of the DSOs the solutions were then reviewed and released for the field tests during the pilot phase.

## Phase 3 – Pilots

In Phase 3, pilot systems were installed in existing MV/LV stations at different locations throughout the Netherlands. During the installation of the systems the impact of installing instrumentation in an existing MV/LV station was investigated.

# REQUIREMENTS

In the SSS document [2] a set of in total 212 requirements were specified, divided under 13 subjects.

- Required system states
  - Specifies the limited number of clearly distinguishable states: Initializing, Fully Available, Reduced Availability and Not Available.
- System capability requirements
  - Specifies the basic functionality as Data Acquisition, Control, Process Data, Data Storage, Data Exchange, Configuration, Logging, Software, (Self) Test functionality, Diagnostics and Power Supply.
- System external interface requirements
  - Specifies the interfaces to external equipment in terms of configuration, software, data exchange and maintenance.
- System internal interface requirements
  - Specifies the interface between the sub systems and MV/LV installation.
- System internal data requirements
  - Specifies the integrity of the internal system data in terms of protection against loss, accessibility and privacy.
- Adaptation Requirements
  - Specifies the ability of the system to be used in existing and new MV/LV stations.
- Safety Requirements
  - Specifies the systems safety requirements.
- Security and Privacy Protection requirements
  - Specifies the security and privacy aspects of all data
- System Environment requirements.
  - Specifies all requirements regarding the environment of the system, e.g. EMC/EMI, climate, shock and bump.
- Computer Resource requirements
  - Specifies the computer hardware and software, including communication interfaces.

- System Quality Factors
  - Specifies the functionality to monitor the quality of the MV and LV power, but also the requirements regarding reliability, availability and upkeep.
- Restrictions Regarding Design and Production
  - Specifies the non-functional requirements regarding modularity, expandability, scalability, reusability, interconnectivity and future proof. But also requirements regarding installation and maintenance.
- Personnel Related Requirements
  - Specifies the role and background of the personnel working with the system.

## BENCHMARK

The SSS document [2] contains of a vast number of requirements. Depending on the level of automation and the location of the MV/LV station not all requirements are always relevant.

To be able to prioritize the requirements, all DSOs shared their vision and motivation regarding instrumentation of MV/LV stations.

One of the drivers to use instrumentation in MV/LV stations is to reduce the outage time for the end user. Common used indicators to calculate the outage time are SAIFI (System Average Interruption Frequency Index) and SAIDI (System Average Interruption Duration Index). In the period from 2001-2011 the average outage time for an LV customer in the Netherlands was 28 minutes per year, 64 % of this was due to breakdowns in the MV network [3].

In the Netherlands 95% of the MV networks are 10 kV with underground cables. The majority of outages due to breakdown in the MV network are caused by a broken cable. The moment the fault location is known, the interruption of the supply can be restored by a number of switching operations in the MV network.

Automating the fault location detection and remote control of the MV switch gear will reduce the outage time.

Another advantage of instrumentation of the MV/LV station is the possibility to realize more advanced remote control of the public lights.

To be able to compare the solutions developed by the coalitions two typical configurations for a KRIS system were defined. One for a so-called non-strategic MV/LV installation and one for a so-called strategic installation.

The requirements for a non-strategic station are stated in Table 1. The labels E.xx in the first column refer to the detailed descriptions in [2].

| KRIS req | Description |
|---|---|
| E.10 | Monitor Thermal Load of transformer |
| E.11 | Monitor Power of LV field |
| E.12 / E.135 | Observe failure / short circuit MV cable |
| E.15 | Register Power of Transformer |
| E.16 | Register energy consumption |
| E.20 | Switch Public Lighting |
| E.21 | Monitor environment conditions station |
| E.22 | Monitor contact state |
| E.23 | Change contact state |
| E.24 | Support remote monitoring |
| E.25 | Support remote maintenance |
| E.27 | Support local maintenance activities |

*Table 1: Requirements non-strategic MV/LV station*

The requirements for a strategic station are the same as a non-strategic station extended with the functionality stated in Table 2. Basically the difference between the configurations is the ability to control the MV fields. Also both configurations should be prepared for Power Quality measurement of a LV field as stated in Table 3.

| KRIS req | Description |
|---|---|
| E.13 | Remote switching Circuit Breaker |

*Table 2: Extra Requirement strategic MV/LV station*

| KRIS req | Description |
|---|---|
| E.14 | Monitor Power Quality |

*Table 3: Requirement Power Quality*

## TOTAL COST OF OWNERSHIP

Although the price of the individual instrumentation components is important, it is only a part of the total cost of ownership (TCO) of the automated substations over the years. To develop a tool to calculate the TCO all aspects influencing the total costs were investigated and categorized.

- *System costs*
  - miscellaneous instrumentation and other components
  - housing
  - assembly
- *Engineering costs*
  - labour costs for engineering and ordering
  - labour costs for configuration of hardware and software
- *Installation costs*
  - for installation of the system in the field
  - site acceptance tests
- *Maintenance costs*
  - maintenance cost over 15 years; for example labour hours and replacement of battery
- *Sensors costs*
  - prime costs for purchasing sensors

Taking into account all expenses during the systems life time gives the possibility to validate the extra costs for

making the system components smart. Spreading these costs over several years gives the possibility to compare them with increased costs of installation and maintenance due to the use of smart components.
The sensors to be used depend strongly on the installed MV/LV installation and in some of the existing MV/LV stations sensors are already installed. Therefore these prime costs are presented in its own category.

For the solution coalition ERE developed, the separation of the TCO over the categories is shown in Figure 3.

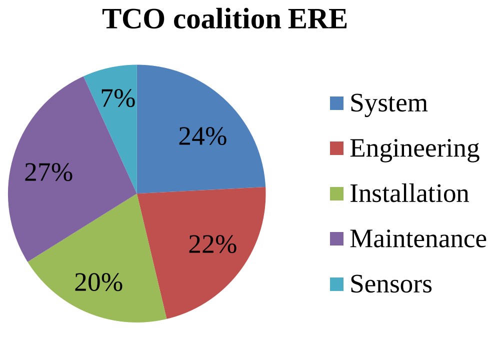


*Figure 3: TCO Contribution per category*

## THE DESIGN

During Phase 2 of the project, each coalition developed its own solution. Our coalition came up with the modular design shown in Figure 4. The KRIS box holds all the functionalities which are required for every RMU.

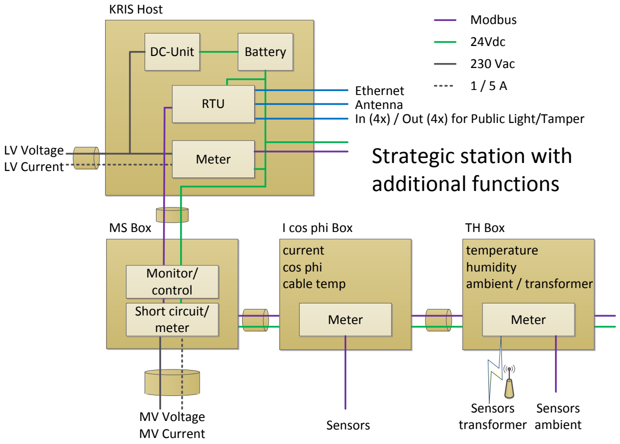


*Figure 4: Architecture of a KRIS solution*

From logistic and maintenance point of view an advantage, because only one box type can be used for all applications. Optional functionalities, not needed for every RMU, are placed in separate boxes.

All boxes are interconnected by instrumentation cabling using standardized connectors securing Modbus communication and power supply. In this way for every application the best combination of boxes can be chosen, while the KRIS box is always the same.

With this design a standard configuration is offered, independent of the installed MV/LV installation. Due to the flexibility of the chosen system architecture, additional wishes can be realized in an easy and cost effective way.


*Figure 5: KRIS host designed by coalition ERE*

The KRIS host includes a power supply with battery backup, which also powers the separate additional boxes. The KRIS host itself derives its power from the sensors used for voltage measurement. These sensors have a build in high capacity fuse; this guarantees a save and easy tapping of the voltage from the main bus bar without downgrading the short circuit resistance of the installation. They are suitable for fuses with a breaking capacity up to 70 kA. Standard compact split-core transformers are used for measuring the current between the MV transformer and the LV distribution rack. The secondary leads of these current transformers (CTs) are prefab mounted on a special connector with an automatic short circuit mechanism to prevent dangerous voltage levels due to an open circuit. Also the output leads of the easy voltage tabs with fuse are prefab mounted in the connector. The connector, including a locking system, is shown in Figure 5.

Not only the hardware but also the software has a modular design. Functions can be activated or de-activated individually. Calibration, scaling and the setting of parameters is done centrally in the KRIS box, including those of the separate additional boxes. Configuring the system can thus be realized in an easy way. This increases efficiency and reduces faults.

## THE FIELD TESTS

After a short pilot every coalition installed four systems at different locations for field testing. One of the sites that coalition ERE equipped was situated in Steenwijk, in the grid of Rendo, a DSO in the eastern part of the Netherlands. During the pre-inspection of the site, dimensions and the positions of the existing MV/LV installation were examined. With this information the interfaces between the KRIS system and the existing MV/LV installation could be chosen. This included the length of the prefab cabling to the sensors and the exact type and size of the transformers and the voltage tabs. Next, the complete KRIS system, including pre-mounted sensors, was build, configured and tested in the factory.

Installation work on site was limited to mounting the individual boxes on the wall and installing the sensors and cabling in the MV/LV installation. Due to the choice of the sensors there was no need to switch off the MV/LV installation.


*Figure 6: Installed KRIS system at Rendo site*

## CONCLUSIONS

Facing the end of the project, the following conclusions can already be drawn.

### Total Cost of Ownership

The goal of the project was to come up with a cost effective instrumentation of MV/LV equipment. For a system suitable in a strategic station the results show that a competitive TCO is put down. However for a system suitable in a non-strategic station, the TCO does not meet the expectations of the DCOs. How can we decrease the TCO? With the underlying specification in mind, lowering the prime cost of the instrumentation itself is difficult. Improvement can be achieved by decreasing the labour hours needed to come to a functioning system. For example, think of standard configurations to cut back on engineering hours.

### New tools condition for success

The introduction of new technologies as part of our solution brought us the insight that attention must be paid to the development of new tools necessary for the successful installation of the instrumentation.
This involves the availability of hardware tools for the installation of new components (for example, new type of sensors in LV-rack and transformer). But certainly also software tools for configuring and identifying local hardware and sensors, the local communication between the separate boxes and remote communication with the back office of the Operations Centre of the DCOs for activation, registration and data transfer.
These new tools must be developed and put different demands on the current installation personnel (additional training necessary) but also to the logistics (and other documentation work procedures) of the project.
This is a not to be an underestimated factor that proved to be a strong influence on the installation time and the success or failure of the Station Automation.

## RECOMMENDATIONS

For future development recommendations can be given.

### Total Cost of Ownership

For the non-functional requirements the SSS [1] does not make distinguish between instrumentation used in strategic and non-strategic stations. Think of requirements regarding the environment of the system, e.g. EMC/EMI, climate, shock and bump.
A discussion should be started to review the desired non-functional requirements for monitoring-only systems. This could lead to a lower prime cost of the instrumentation itself.
Lower prices itself could open new markets and a broader use of monitoring systems in MV/LV systems.

### New possibilities with automated stations

The KRIS system is designed to realize data communication with external systems as SCADA and back offices. The availability of actual data gives the possibility to realize new functionality. Some examples:

- *Preventive maintenance*
  Locate weaknesses in the system based on slowly changing average measurements. Think of a transformer which slowly degenerates.
- *Balance management*
  Knowing the actual energy flow in the grid gives the opportunity to maintain the balance.
- *Capacity management*
  Pricing energy use, based on time and place, gives the opportunity to flatten the peak.

Roll out of these functions will change the business case and can result in higher volumes.

## REFERENCES

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