Secure Integration and Rollout of IEC 61850-Based Smart Components Within the iniGrid Project

Stephan Hutterer
Sprecher Automation GmbH - Austria
stephan.hutterer@sprecher-automation.com

Wolfgang Hauer
Eaton Industries GmbH - Austria
wolfganghauer@eaton.com

Johann Meindl
Sprecher Automation GmbH - Austria
johann.meindl@sprecher-automation.com

Friederich Kupzog
AIT Austrian Institute of Technology - Austria
friederich.kupzog@ait.ac.at

ABSTRACT

The paradigm shift to smart grids necessitates technological innovations in manifold areas. Especially at the distribution level, cost-effective components will be needed that enable advanced functionality such as communication and control abilities, and can be rolled out with reasonable effort and in a secure manner. In a consortium of 8 industrial and scientific partners, Sprecher Automation GmbH, Eaton Industries (Austria) GmbH and AIT - Austrian Institute of Technology GmbH target this window of opportunity right now within the iniGrid project in order to provide key technologies for future smart grids.

INTRODUCTION - INIGRID PROJECT OUTLINE

As a consequence of the massive integration of renewables, active capacity management in distribution grids will become necessary in order to avoid high investments in grid reinforcements [1]. Management of line use in congestion situations, as well as fault detection and fast service restoration, are only possible with appropriate sensors and actuators in place. Appropriate cost-effective components that provide advanced functionality such as integrated communication capabilities and can be retrofitted with reasonable effort are missing today at the distribution level. The market is beginning to request such devices on low and medium voltage level. The Austrian research project “iniGrid” therefore aims to develop and validate innovative sensor and actuator components for smart distribution grids.

Content

Two radically new sensor and actuator developments, along with the necessary information/automation technology, are in the scope of the project. These items will fill the gaps in the required observability of distribution grids for future grid operation: the first key innovative approach of iniGrid is the integration of the power management and grid protection functions within one device, called the SmartBreaker. The challenge is to integrate necessary components in a compact device with reasonable costs. These innovative switching devices are located in the energy customer domain (low voltage, mostly commercial/industrial customers) to provide protection functions, power management, measurement services and communication for individual load or generation branches. The second innovation is an air-insulated medium voltage sensor, integrated into post insulators or other insulating structures for retrofit of the significant number of existing air-insulated medium voltage installations. The challenge here is to provide precise data since these isolators have no earthed cover and therefore suffer from parasitic capacitances to geometrically and electrically (switching state) undefined external structures.

Challenges

The project deals with the individual technology development and the integration of these novel components (as well as existing ones such as smart metering and other sensors) with future-proof and secure automation architecture and protocols. The challenge addressed in the liberalised market environment is how to technically and conceptually network sensors and actuators in the smart grid for applications ranging from local energy management to virtual power plants, grid voltage control, fault detection and others.
An increasing number of such networked smart grid applications are emerging. Together with the push for PV and other distributed volatile generators into low voltage networks, a strong pressure for innovative and cost-effective sensor and actuator technologies is developing. iniGrid aims to provide cost-efficient sensor and actuator technology for actively managed distribution grids.

The focus of this paper shall be to describe iniGrid's project aim in the context of the application of SmartBreakers. Therefore, the next section introduces this technology, its motivation, details, and challenges. Subsequently, the secure integration and rollout of SmartBreakers through appropriate power system control and automation technology will be addressed. In the end, concluding remarks complete this work.

CUSTOMER-LEVEL MEASUREMENT AND CONTROL WITH SMART BREAKERS

Motivation

Leading European power system companies as well as research institutes [1] and international organizations [2] all underline the challenges the power grid will face within the upcoming next decades. These challenges include, but are not limited to continued increase of electricity consumption, the need to shave peaks and

balance energy consumption, as well as the growing integration of various energy sources into the power system. The shift towards extensive distributed energy generation demands new functionalities from the power grid infrastructure, such as capacity management on distribution level. Prerequisites for this are advanced energy monitoring, as well as active management of grid-connected resources, for instance, loads, battery systems, or photovoltaic systems. These tasks define the set of Smart Grid functionalities such as energy flow tracking, peak clipping and reactive power management supported by a novel component explored within the iniGrid-project, the so-called SmartBreaker.
The elaboration in the following paragraphs concerns the general description, features, specifications and possible applications of the SmartBreaker.

SmartBreaker concept

Like a conventional low-voltage circuit breaker, the SmartBreaker primarily serves to protect electrical power systems by detecting abnormal conditions, such as overloads and short circuit currents, and consequently interrupts the circuit automatically and safely.
Due to its novel design, the SmartBreaker can also act as a contactor switch allowing very high switching cycles, needed for everyday power switching in a power management application.
Furthermore, the SmartBreaker provides remote control functionality in order to switch on or off a circuit remotely. Currently, a shunt trip and a reclosing unit in addition to a circuit breaker are needed for this make/break functionality, as shown in figure 1. The device also includes Smart Meter functionalities such as power/energy monitoring and load profiling.
These offered features will perfectly meet the future customer's requirements for an anticipated Smart Grid scenario.

Protective Functionality

In addition to the overload and short circuit current protection, the SmartBreaker incorporates the protection functionality of a residual current circuit breaker and an overvoltage trip (see figure 1). Hence, it is able to detect and report critical conditions, for example increased residual current and over- or undervoltage in power grid before any damage is caused.
The SmartBreaker will be designed for nominal rated currents of up to 125 A in a 230/400 V AC system with a short circuit breaking capacity of up to 20 kA.

Remote Control Functionality

The remote control functionality implies communication capabilities. The SmartBreaker uses a proprietary 2.4 GHz wireless network protocol based on the IEEE 802.15.4 standard [3] for wireless communication with a remote terminal unit (RTU) as shown in figure 2.

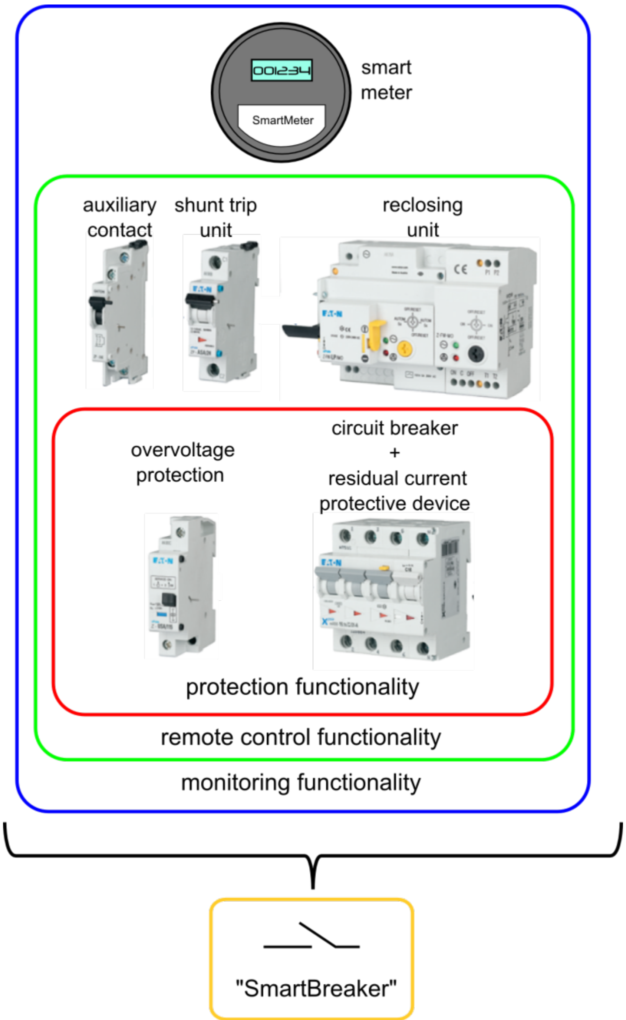

Figure 1: SmartBreaker concept

The advantage of the wireless communication over wired communication is the low set-up effort because no additional wiring of auxiliary circuits is needed. The disadvantage of the relative low broadcasting range (up to a few hundred meters) is acceptable since the wireless communication takes place within a switchboard cabinet only, and they are limited in size. Outside of the switchboard cabinet wired communication is used (see figure 2).
The RTU may be interfaced to multiple master stations via different communication media (RS232, RS485, RS422 or Ethernet). It does support several standard protocols (Modbus, PROFIBUS and IEC 60870-5-104) to interface to any third party software.
One goal of the iniGrid project is to implement IEC61850 based communication protocols in the communication interface of the SmartBreaker which enables the device to be part of power utility automation systems of all levels. This will allow e.g. a gateway access from a smart substation at the medium-voltage grid side to the SmartBreaker at the low-voltage grid side.

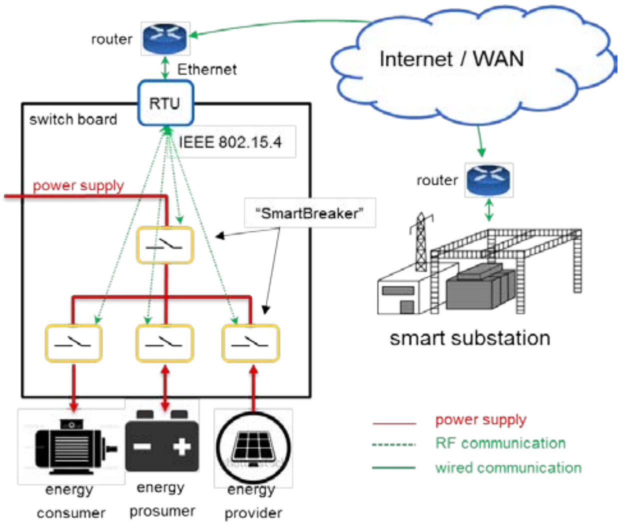

Figure 2: SmartBreaker communication

A set of getter and setter functions will be provided in order to have full control over the SmartBreaker remotely. These functions include, for example, get/set switching position (ON/OFF) or get/set the tripping characteristic of the SmartBreaker.

Monitoring Functionality

The SmartBreaker also includes advanced current and voltage transducers which allow real-time measurement of current flow and voltage condition at its location. Parameters such as power factor, power/energy flow, and active-, reactive- and apparent power can be calculated subsequently based on the measured current and voltage values. The data can be stored and reported to a remote user. Users such as energy consumers, prosumers, transmission/distribution system operators, energy service companies, virtual power plants and retail energy service providers can use this monitoring feature in order to enable different kind of applications. For instance, real-time energy flow management, demand side management, demand response customer-oriented programs, identifying location and extent of power losses, theft detection, tamper detection and outage detection and management. It also allows condition- and performance-based maintenance of the network such as automatic reconfiguration of feeders or optimization of voltage level and reactive power.

Challenges

Due to the novel switching design of the SmartBreaker equipped with both communication and metering interfaces, several challenges may arise especially when developing a circuit breaker capable of switching off overload current or short circuit current as high as 20 kilo-amperes.
Another issue to consider is the miniaturization of the SmartBreaker components. The challenge is to incorporate the functions needed for power protection, power metering/management and communication in a single, compact device at reasonable costs.
The switching technology of the SmartBreaker also needs a fast and reliable detection of overloads and short circuit conditions. Hence, an overload and short circuit detection algorithm that additionally prevents unintentional, or nuisance, tripping of the breaker is needed.

A further challenge is the integration of the SmartBreaker with future-proof and secure automation architecture and protocols into power systems' IT infrastructures.
In addition there is the challenge brought by the liberalised market environment: how to technically and conceptually incorporate the SmartBreaker in a Smart Grid with the integrated applications ranging from local energy management to virtual power plants, grid voltage control, fault detection and many others. Therefore, interoperability and ease-of-configuration are major requirements, that shall be addressed by appropriate automation and communication technology as addressed in the next section.

SECURE AUTOMATION NETWORK INTEGRATION

Within this context, Sprecher Automation aims at implementing appropriate control and communication infrastructures in order to incorporate novel sensor and actuator technologies into power grids. While the functional requirement is to efficiently embed the developed components (smart breakers and voltage sensors) into the power system, additional requirements concerning IT-security are put into play. The approach for solving this issue shall now be presented with special emphasis on integrating Smart Breakers.

Communication/Integration Concept

The idea is to provide a generic technical solution to integrate smart breakers into superordinate systems such as power grid control systems. By this means, smart breakers shall be accessed from any control system and be applied for manifold tasks ranging from use cases such as power/energy monitoring to demand-side management.

Figure 3 visualizes the concept of integrating Smart Breakers into a holistic control system. While the Smart Breakers provide their functionality through the set of aforementioned getter/setter functions (such as get/set the switching position), Sprecher Automation incorporates an intermediate control device that maps these functions and offers them through domain-specific protocols (such as IEC 61850 and 60870-5-104) to higher level control systems in the power grid domain. Hence, the provided breaker functions can be accessed from from e.g. any arbitrary grid control system through standardized protocols, enabling the generic integration of Smart Breakers into power systems.

Here, a specific use-case will be the application of IEC 61850-based communication for substation automation. Therefore, the breakers' functionality will be mapped to an IEC 61850 model of intelligent electronic devices, which facilitates their integration into substations and offers the breakers' functions to any control device that features this communication standard.

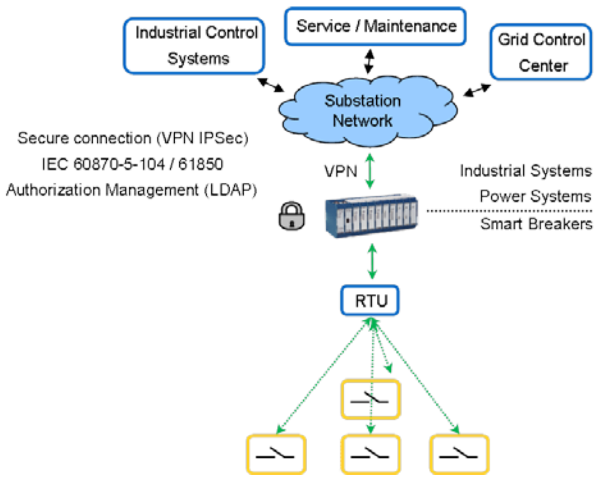

Figure 3: Communication/Integration Concept

Security as a Principal Requirement

Beside the generic integration into power grid control systems respectively communication infrastructures in the power grid domain, another major requirement concerns increasingly important security concerns in such systems.

Sprecher Automation early identified the upcoming importance of security issues in the power grid domain and is already able to provide sophisticated security features in control devices (such as indicated in Figure 4) and continuously investigates potential expansions of the offered product portfolio with respect to IT-security.

Therefore, within the iniGrid project a central aim is to investigate concepts for secure rollout and installation of control systems such as SmartBreakers. As indicated in Figure 3, one important building block is the secured end-to-end connection via IPSec tunnels e.g. for installation or maintenance issues. Another important point is the appropriate user authorization management as well as the related secured administration of authorization data. Here, several questions need to be addressed such as where to efficiently store authorization data (in the context of potential hacking attacks or outages of communication networks), or how to define an optimal trade-off between usability and security, which is an ubiquitous conflict in IT systems.

Figure 4: Exemplary IT-Security-Integrated Control Device

CONCLUSION

The iniGrid project addresses the development of cost-effective components for medium- and low-voltage networks, as well as their secure integration and rollout into power systems. One central application within this context will be the development and integration of Smart Breakers, which aim to provide load monitoring and control functions for decentral applications. Based on this idea, Sprecher Automation provides a generic concept for integrating this technology into power grid control systems, while IT-security is an increasingly important concern that necessitates continuous research work.

Finally, within the research project both technological developments and conceptual investigations will be proven in field trials both in laboratories as well as real world scenarios.

ACKNOWLEDGMENTS

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REFERENCES

[1] J. Büchner, J. Katzfey et al., 2014, „Moderne Verteilernetze für Deutschland“, *Study issued by the German Federal Ministry of Economy and Energy*, (in German language)

[2] J.G. Kassakian, R. Schmalensee, et al., 2011, “The Future of the Electric Grid”, ISBN 978-0-9828008-6-7, Massachusetts Institute of Technology, Boston, MA, USA.

[3] European Commission, 2006, *EUR 22040 — European Technology Platform SmartGrids*, Office for Official Publications of the European Communities, Brussels, Luxembourg, (pp 6-7).

[4] IEEE802.15.4-2003, 2003, *Wireless Medium Access*