THE RIESLING PROJECT - PILOT PROJECT FOR INNOVATIVE HARDWARE AND SOFTWARE SOLUTIONS FOR SMART GRID REQUIREMENTS

Juergen BACKES
EnBW ODR AG
j.backes@odr.de

Christian KOERNER
EnBW Regional AG
c.koerner@enbw.com

Volker GRUENEWALD, Werner KREMER
T-Systems
werner.kremer@t-systems.com

Stefan KAEMPFER
ABB AG
stefan.kaempfer@de.abb.com

ABSTRACT

The project RiesLing (Projekt im Ries – Leittechnik intelligent gemacht, translated „implementation of an intelligent grid control in the Ries area“) focuses on the development and the practical test of solutions which according to the project partners represent core components of a Smart Grid. The region of its implementation is the Nördlinger Ries, a region in the north-western part of Bavaria and in close vicinity to the federal state of Baden-Württemberg. This area combines a maximum load of around 50 MW with a maximum generation of around 120 MW, mostly from Photovoltaic modules and biogas fuelled engines. The RiesLing project has been initiated in mid 2011. Its technical implementation is set up as three separate packages. Two of these packages are dealing with innovative secondary equipment and communication solutions. These have been finished until end of 2012.

Until mid 2013 additional functions for the grid supervision and control will be implemented, addressing power flow forecast and grid state estimation. The implementation phase will be followed by a test period, lasting until December 2013.

This paper describes the aspects covered by the project and presents some of the results obtained until end of 2012.

INTRODUCTION

The *RiesLing* project is a joint activity of four partners. Two of them are technical solution providers: ABB AG provides technical solutions for primary and secondary equipment used within medium voltage (MV) distribution grids, the domain of Deutsche Telekom, a German telecommunication network operator, is the telecommunication infrastructure for the project. Further partners are EnBW Regional AG, a distribution grid operator from the South-West of Germany in the Federal State of Baden-Wuerttemberg, and EnBW Ostwuerttemberg Donau-Ries, a small German utility operating the distribution grid where the *RiesLing* project is taking place. The idea of the project is to develop and test technical packages, which will form the basic components a Smart Grid is composed of.

Figure 1 shows the timeline of the project, which consists of 3 packages.

- In package 1 four existing MV substations are equipped with online measurement and online monitoring via secured and managed communication.
- In package 2 another four MV substations are upgraded using new MV compact switchgear including remote operation via secured and managed communication and additional functionality. An additional substation, the "Smart Module" is a compact module that includes voltage control for the LV system supplied by the substation.
- Package 3 is using the online information from the equipped substations to improve load flow estimation and grid state forecast.

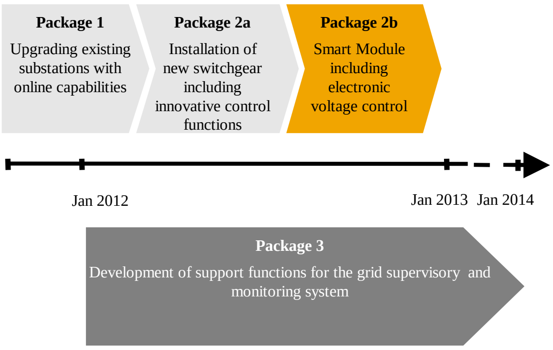

Figure 1: Structure and timeline of the *RiesLing* project

CALCULATING MV VALUES FROM LV MEASUREMENTS

To observe a grid including a large number of dispersed generation units, it is necessary to have access to more online measurements than typically available today in German grids. Current measurement within a MV/LV transformer substation is easily implemented, as current transformers can be clamped around the insulation of cable conductors. Precise voltage measurement however is expensive. It requires voltage transformers and/or sensors connected directly to the MV level. Besides relevant additional cost this leads to potential sources for insulation problems in the grid.

The solution implemented in the *RiesLing* project thus eliminates the voltage measurement on MV side and substitutes it by a calculation from values measured on the LV side. The voltage is using the power transformer as a quasi-instrument transformer. The impact of the power flow through this transformer on the voltage measured on the LV side is calculated and used for estimating the value of the MV voltage.

The configuration of voltage and current sensors used is shown in Figure 2. The voltage is measured on the LV side and is fed to the RTU (remote terminal unit). This RTU is the central control device within the substation (S/S) and is connected to the managed communication platform.

In addition to the calculation of the MV side values, the RTU also permanently monitors the MV phase currents and generates signals for overcurrent detection. It also identifies pulsating ground faults which are used to locate a phase-to-ground fault, if occurring in the grid. Today both functions are provided by dedicated sensors. These can be eliminated, which reduces cost, saves space and avoids operational cost for cabling.

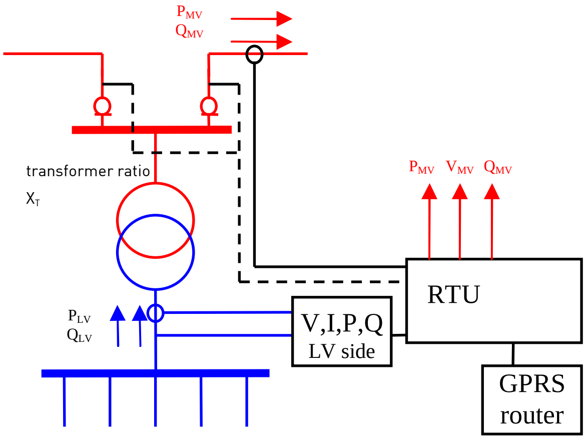

Figure 2: Secondary equipment used in *RiesLing* S/S

The view inside the cubes with the control equipment is shown in Figure 3.

Figure 3: View of the control cubes installed

LV GRID VOLTAGE CONTROL

As mentioned in the introduction one of the substations, the "Smart Module" is equipped with LV side voltage control. The technical solution implemented is shown in Figure 4. A conventional transformer 20 kV/0.4 kV with a rating of 400 kVA provides the uncontrolled low "raw" voltage. The voltage then is conditioned by a series transformer, fed by a static converter. This configuration working as an AVR (Automatic Voltage Regulator) adds a correction voltage with a maximum magnitude of 10% phase-to-phase voltage and any angle possible.

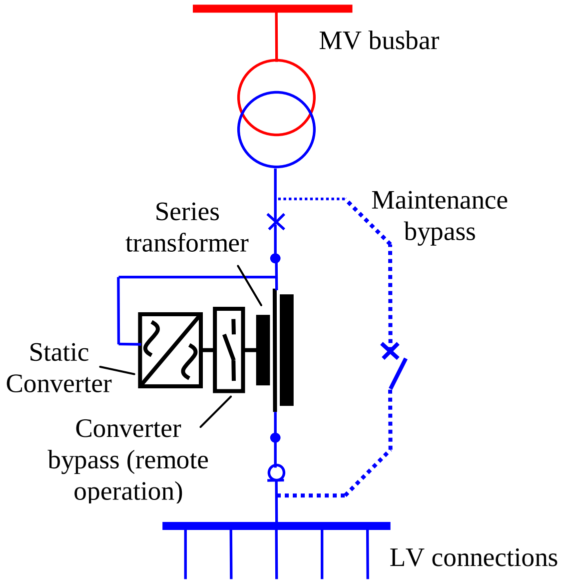

Figure 4: Technical solution for the voltage control

To avoid a major impact of the voltage control device on the supply of the LV grid in case of component maintenance or failure, the AVR is equipped with two bypasses. The internal bypass within the AVR can be remotely operated and thus activate or de-activate the AVR. An additional external bypass that must be locally operated completely disconnects the AVR from the LV grid supply chain.

Figure 5: The "Smart Module", view towards the AVR

Besides the test of the AVR itself, one of the main objectives of the project is to compare different strategies for voltage control of a LV grid. An overview over the different concepts is given in Figure 6.

The “trivial” control mode, named as mode 1, is control based on a fix set point for the LV grid voltage at the transformer connection.

The second mode is a voltage set value determined depending on solar radiation. The radiation is measured by a respective sensor. This control mode lifts the voltage set point in case of weak solar radiation and reduces the value when solar generation is expected to be high.

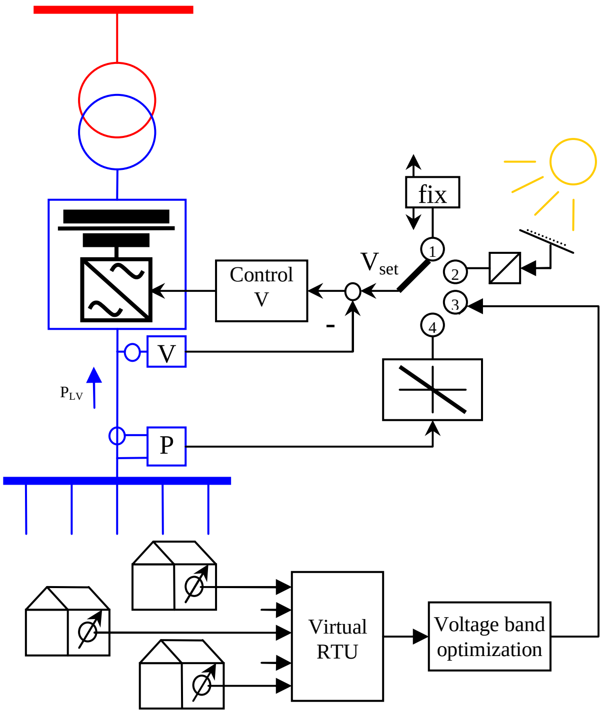

Figure 6: Different voltage control concepts to be tested in the *RiesLing* project

Control mode 3 measures the voltage at selected meter installations in the grid. To provide these measurements the project is using devices which not only meter the energy consumed/generated but also measure the 3 phase-to-ground voltages and provide these measurements to the grid control and to the local substation control. Based on these measurements the voltage control optimizes the voltage set point for the LV grid. It is obvious that this control mode allows an ideal adaption of the LV grid voltage to the grid situation, if sufficient voltage measurements from the grid are available. It however requires distributed measurement infrastructure and additional communication effort.

Control mode 4 uses a reference value for the set voltage which is increased or decreased proportional to the load flow through the MV/LV transformer. This control mode thus only requires local measurements available within the transformer substation. It limits the technical complexity and reduces the communication requirements.

COMMUNICATION INFRASTRUCTURE

A secure and reliable communication infrastructure is a basic requirement to Smart Grids. One of the project objectives of *RiesLing* is to find out to what extent a managed, secured and cost-efficient communication based on a mainstream infrastructure is adequate for the requirements of a distribution grid operator. The *RiesLing* communication network is an infrastructure which is provided as a service to the distribution grid operator. Communication is operated and administrated by the project partner Deutsche Telekom,covering not only reliability and security but also privacy of the data transmitted. Its structure is shown in Figure 7.

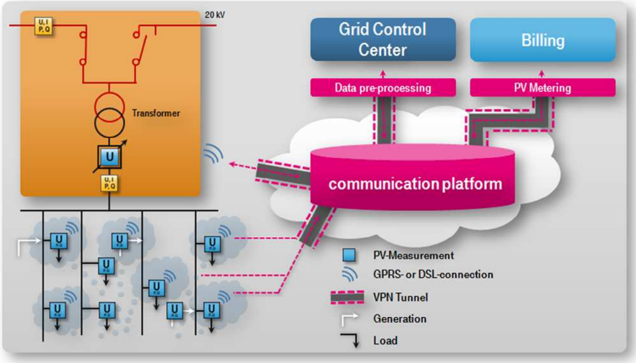

Figure 7: *RiesLing* communication infrastructure

Its main features are:

- Implementation as a protected private network;
- Uniform access to the communication network, independent of the type of physical access for an individual TCP/IP connection (Mobile data communication, DSL, Cable).
- Management of the communication infrastructure as a service to the grid operator, including security certificate handling. To the grid operator this offers the advantage that no internal competences and resources are necessary.
- Using a single communication platform, suitable for applications of limited bandwidth requirements (meter data access) as well as for applications with higher data transfer volumes (control and supervision of substations).

As described in the previous section, one of the voltage control modes of the smart substation requires technical measurements for the voltage at the customers’ grid interface. To provide these values some selected customers at strategic locations in the LV grid were equipped with Smart Meters. These do not only meter the energy exchanged with the grid but also deliver technical measurements (active and reactive power, per phase values). The signals are locally monitored by the meter and transferred to the SCADA system only in case when the variation exceeds a pre-defined threshold. The minimum time step between the transmission of measurement updates has been set to 5 s.

The metering data and the technical measurements are handed over to the grid operator (who also is the default measurement system operator) via two different interfaces. The metered data use secure ftp transfer based on a protocol standard for meter values. For the technical data the telecommunication partner has designed a “SCADA-Interface - Virtual RTU". It provides the measured values in the format according to IEC-60870-5-104. Thus they are accessible to any standard tools for grid supervision and control.

GRID STATE SUPERVISION AND FORECAST

One of the central concepts of a Smart Grid is to control grid assets and devices connected to the distribution grid depending on the grid state. When a grid locally approaches to its capacity limits for load and/or generation, e.g. due to outages or due to planned maintenance, this must be detected. Adequate measures acting on flexible loads, storage devices or generation units are initiated.

It has been a consensus among the *RiesLing* project partners that a complete coverage of the MV/LV grid by dedicated measurements is not to be expected during the next years. Therefore a methodology has been designed that uses forecasted time series data for loads as well as for generation units instead of measurements. To achieve better precision these forecasted values in the next step are calibrated using the available measurements in the grid. The grid state thus is estimated based on partial (but incomplete) measurements and prognoses based on the behaviour of the grid in the past.

The procedure is shown in Figure 8. To each MV/LV transformer substation has been assigned two components for load and generation. These components are assigned the expected values of the respective active power. In fact the load component considers the installed power values of two categories: private households and commercial/industrial loads. The generation component differentiates between photovoltaic generation (PV), wind and others (biogas, biomass, hydro, combined heat-power modules).

The forecast value of the time series for the load is selected from comparable situations in the past (season, week-day, temperature) for each customer category. For the generation the expected value considers the installed power for each generation type in combination with forecasts their present contribution. The individual substation forecasts are superimposed at feeder level, where the aggregated forecast can be compared to the existing measurements. Based on this comparison the customer type specific load curves are calibrated to fit the measurement. In the final step the calibrated load curves are used to refine the active power values of the substations and to analyse the power flow over the branches of the MV grid. The calculation procedure has been successfully tested during a bachelor thesis together with the University of Applied Science in Karlsruhe Germany [4] and should be implemented by Q2 2013.

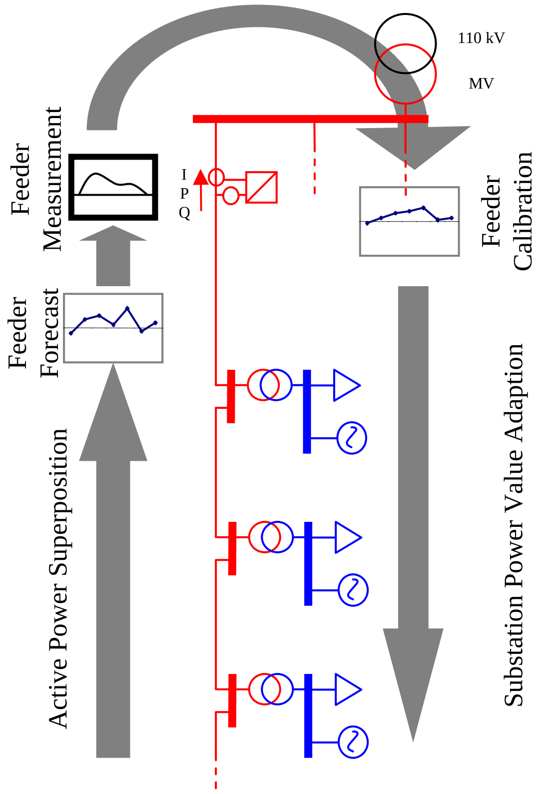

Figure 8: Power flow forecast and calibration process

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