# MICRO GRID CONTROL STRUCTURES FOR BETTER INTEGRATION OF RENEWABLE ENERGY

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## ABSTRACT

*Driven by the increasing need to expand grid capacities due to the sustained integration of distributed renewable energy sources (especially photovoltaic generation in low voltage grids), solutions for an economic justifiable approach are needed. The majority of the provided options by the OEMs lead to an increased amount of data and control complexity in order to operate the additional equipment. To avoid dependencies on a higher control instance and to reduce the needed effort to operate a distribution grid covering a large area, local control strategies could provide a solution. In a small village, the EnBW electricity company runs a pilot project and tests different options for low voltage (LV)-grid load shedding. To implement and validate control structures under real conditions is an inherent part of the research program.*

*This paper shows the general approaches chosen for the design of a control system as a local micro grid, as well as the first results from the phase of practical testing.*

## INTRODUCTION

Due to the sustained integration of renewable energy sources into the distribution grid, more and more areas reach the point where locally generated power is pushed back into the higher grid levels. After the events in Japan, the German government also increases the efforts for a fast nuclear phaseout. Combined with global climate change initiatives, incentives for renewables and reduction of $CO_2$, the issues related to the distribution grid increase further. At this stage, some areas in southern Germany already produce up to six times more electric power than they normally consume. In the year 2011 over 18.000 GWh of electric power were generated in more than 880.000 photovoltaic (PV) sites all over Germany [1], most of it in form of private installations at the LV- grid. This results in a massive load fluctuation to the distribution grid which is already operated at the technical limit. In addition, most PV-sites are located in rural areas dominated by voltage stability problems other than current limitations. Big differences between maximum power generation during a clear day and minimum generation e.g. at night, also intensify the problem. To prevent a massive conventional grid expansion leading to overcapacities that are rarely used, new technologies summarized as “smart grid” can be a way out. The goal of the project described below is to identify and evaluate promising technologies and combine them with new control mechanisms to get an integrated solution for new grid concepts.

## METHODS FOR LOW VOLTAGE GRID CONTROL

To establish a new decentralized grid control and test it in a pilot project, different methods have been selected for a combined solution. The main approaches can be clustered in four areas described below.

### Measurement

To validate and compare different approaches for better grid utilization, a large scale measurement is needed. In the first place these measurements are used to identify possible congestions and other grid restrictions during the normal operation of the grid. First analyses have shown that PV-generation and clouds alternating with sunshine lead to a high dynamic load fluctuation, sometimes within seconds. The used grid inspection strategy has to take in to account this requirement for the measurement resolution. The approach for this problem is therefore based on two different technologies. A high frequent measurement inside the substation is monitoring the load and voltage on all MV and LV lines connected to the substation every couple of seconds. In addition smart meters are installed at the customers sites providing 15 minute mean as well as min and max values for load and voltage level from decentralized positions all over the grid. All measurement information will be transferred and collected at the substations for control purposes on site or analyses later on.

### Selective reduction of renewable energy production

According to the local regulations, the grid is designed to handle maximum possible load even if this capacity is only used in a few hours per year [2]. To avoid cost intensive extensions of the grid, a possible solution is to reduce the amount of produced energy during these hours of the day when the capacity limit is reached. Because the voltage threshold is the limiting factor, a simple system reducing the generated power can achieve a sufficient relief to the grid stability. Therefore it measures the actual locale voltage level and controls the output of previous defined critical generation sites.

### Regulated Distribution Transformer

The use of regulated distribution transformers can be one key solution for voltage related capacity problems in LV grids. The possibility of changing the transmission ratio during operation without the need for a supply interruption allows a situation based behavior of the transformer. In situations with high decentralized generation and accordingly high voltage, the transformer automatically increases the transmission ratio, lowering the voltage at the LV side. In times with low generation but high power consumption the voltage level decreases along the lines triggering the transformer to increase the voltage level. This procedure ensures that all connected customers are provided with a voltage level within the allowed range (±10% for Germany [3]) unaffected by local load situations or MV voltage levels. Although the regulated distribution transformer can provide a viable solution for a lot of problems, it has its restrictions if decentralized generation and loads are not homogeneously located within the grid. The voltage drops at different lines can then lead to a large spread at the end positions, limiting the transformers range of operation.

### Decentralized Energy Storage

Energy storages in general can be used to reduce the load on a grid temporarily by absorbing energy in times of high generation and discharging in times of high energy consumption (load shifting). For a maximum effect the battery has to be placed at a strategic position which can be determined by simulation beforehand of the LV-grid.
At the same time, an energy storage based on Li-Ion technology can switch fast (<15 seconds) from a charging to a discharging state and vice versa, providing a high dynamic in power adaption. With this ability, voltage fluctuation due to volatile PV-generation and cloud influence can be leveled in real time.

With high potential all for their own, an optimized result can only be achieved if the methods mentioned above are combined in a holistically concept. Therefore, information has to be transferred between the single components and actions have to be coordinated. The approach for a decentralized local area control mechanism is described below.

## MICRO GRID CONCEPT

Every method described needs information and control signals in order to cooperate with other devices and respond properly to the current task situation. In addition, each device creates signals itself, useful for others. In a large grid, providing millions of customers, a single control instance would hardly be able to handle all the information from thousands of devices, not to mention the additional control loops needed. As most of the operational decisions only concern local problems, either one single LV grid or a maybe a MV line, the use of local control and monitoring equipment is reasonable.
A concept for such a local decentralized and autonomous control structure referred to as “micro grid” is described below.

### Micro Grid Concept

Other than proposed in [4] no physical separation or islanding is sought for the concept of the micro grid described here. Through the implementation of the control architecture only an additional data layer is created to separate the different levels of operation. The goal is to optimize the local grid management, but also including orders coming from higher grid levels or control mechanisms. By clustering the control task into local instances, the communication traffic to the higher control levels is reduced significantly as most of the information is processed and exchanged locally.
To achieve the challenge of a better asset operation grade it is inevitable to dimension the grid not for the maximum load, which only occurs a couple of hours a year, but to manage generation and load inside the grid operation parameter. This overcrowding is only possible if eminent focus is laid on a complete failsafe operation even after a broad communication blackout. Therefore the micro grid control is designed to operate the local instance even without a permanent connection to a higher SCADA (Supervisory Control and Data Acquisition) system. Even when the micro grid control itself is malfunctioning or out of order, each individual part of the grid (storage, power reduction, transformer) will fall back into a safe mode and try to maintain the power supply.
The control hardware itself is located inside the secondary substation. From here it communicates with all available devices in the LV-grid and distributes information and control signals. For example, it is possible to detect high voltage areas via the smart meter infrastructure and instruct the regulated transformer to adjust the voltage level. At the same time, large voltage differences between different lines can be detected and line specific devices like reduction of generation capacity or energy storing inside the battery can step in.

## PRACTICAL EXPERIENCE

To gain practical experience for the concepts described above and compare different technologies, EnBW runs a pilot project addressing the better integration of decentralized renewable energy into the LV-Grid. As a result, every tested technology should be benchmarked considering a possible large scale roll out to the entire grid. Therefore testing under real conditions within an actual grid was inevitable. After analyzing possible sites, the low voltage grid of the village SONDERBUCH was chosen. Located halfway between STUTTGART and LAKE CONSTANCE with a population of 190 people, SONDERBUCH is known for an unusual high amount of photovoltaic generation. With 60 independent units an overall amount of 1.2 MW is generated facing only 0.2 MW of maximum load. By the year 2009 the accumulated annual energy production in this village has exceeded the overall energy consumption.

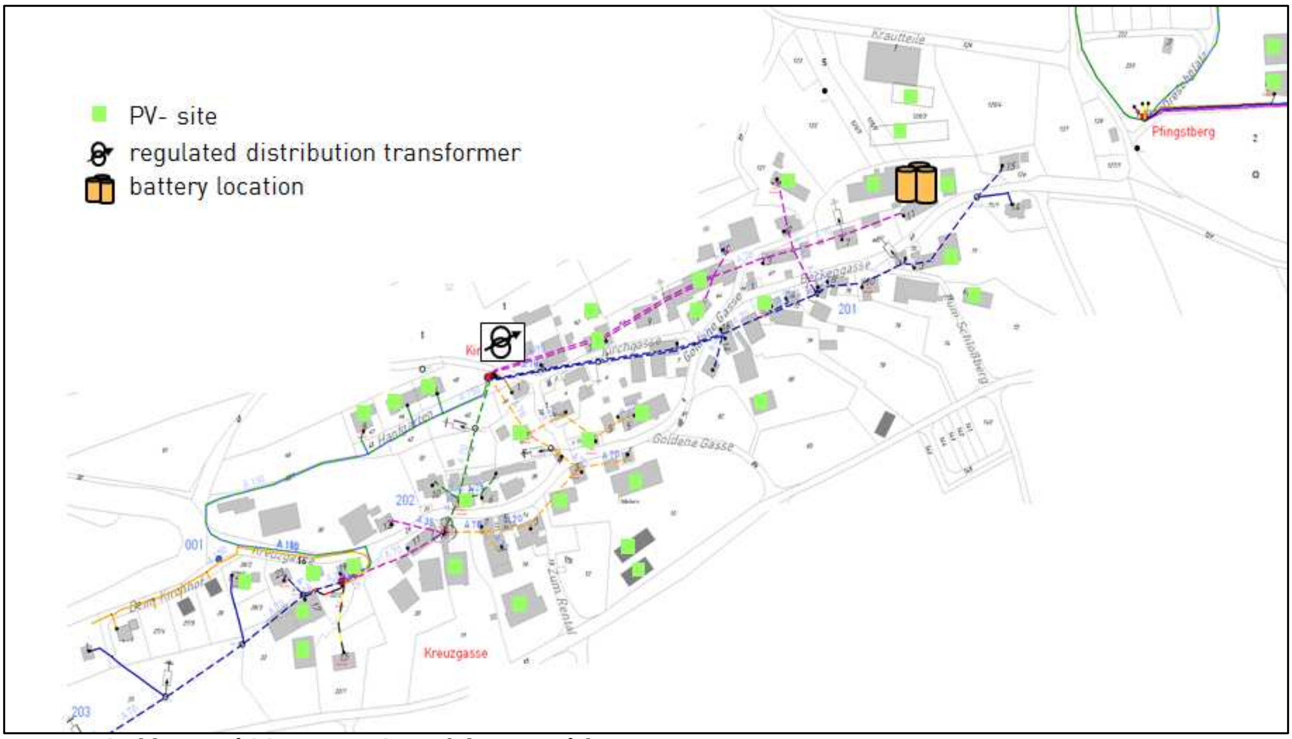


Figure 1: Grid layout of SONDERBUCH with location of the control equipment

Taking into account, that energy production is only possible during 1200 hours of equivalent full sunshine a year, still more energy is produced during this time than consumed in the rest of the year.
With this outstanding amount of decentralized renewable energy production SONDERBUCH is not representative for the current situation, but a good foresight regarding predicted developments for the renewable expansion.

By now, half of the households are equipped with intelligent metering systems gathering grid information like voltage, current, load and phase angle. This information is transferred via small band power line communication to the secondary substations. Additional hardware inside the substation aggregates the data and serves as a local control instance similar to the system introduced in [5]. Here is where the local grid optimization takes place. To affect the grid, it will be possible to control the amount of produced energy from the photovoltaic systems.

It's also planned to include a 16 kWh electric battery and an automatic regulated transformer, both controlled by the local optimization hardware. A full operational micro grid is scheduled for mid of 2012, when the practical testing begins in full scale.

In the end, the system should be capable of providing a safe and reliable grid operation with the benefit of a better operation grade.
Not only can more decentralized generation be integrated without the need of expensive expansions, also better information from the low voltage grid is available together with communication infrastructure allowing a fast response to critical situations.

## REFERENCES


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