FIELD EXPERIENCE OF PHASORS MEASUREMENT IN A DISTRIBUTION NETWORK WITH INCREASED LEVEL OF LV-CONNECTED PV

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ABSTRACT

BKW is the leading Swiss power utility serving about 1 million consumers.
Due to the new government energy policy of incentivising the use of LV-connected micro-production units (in particular PV) and following the likely abandonment of nuclear energy production in Switzerland, BKW is expecting high fluctuations of the power flows on the network due to the high level of injected renewable energy at the LV side of the network.

In order to mitigate and prevent the conceived problems on the onset BKW has tested in its network a new smart grid device that works as a low cost phasor measurement unit. The aim is of potentially implementing this feature at critical points in the medium and low voltage grids within the context of a plug & play smart transformer distribution station solution. In the near term, BKW aims at implementing a low cost smart grid monitoring and control system for the LV grid. This would allow to validate whether the real time analysis of the behaviour of the LV network voltage levels will enable dynamic regulation the power factor. As a consequence, stability and reliability of the distribution network shall be kept within acceptable limits even with high penetration of decentralized intermittent microgeneration at the LV grid side.

INTRODUCTION

A phasor is a mathematical representation by means of the amplitude and phase angle of a sinusoidal electric signal. “Synchrophasors” is the synonym for synchronously measuring phasors . The respective devices that allow this kind of measurement are called PMU (Phasor Measurement Units).

A Synchrophasor measures the electrical sine wave simultaneously in several parts of the grid by using a common time source such as GPS (Global Positioning System) for the purpose of synchronization. By comparing in real time all these measurements a dynamic state estimation of the health of the grid can be determined such as Power Quality (PQ) levels, THD (Total Harmonic Distortions), etc…

Recent progress in microelectronics and in communications technologies let envisage that PMU could be reaching soon a reasonable price that would allow their use also in distribution grids.

The PMU could be either deployed as a stand-alone device or as dedicated function in a smart grid controller device.

“Small is beautiful”. In economics theory this has been an interesting paradigm change. One of the main challenges in building up a smart grid ecosystem is to optimise the Return on Investment (ROI) and to figure out which “killer applications” that should first be implemented.

The goal of the project was to show whether it was possible to estimate the system state of BKW´s LV grid by simultaneously measuring phasors of voltages and currents in neuralgic points of the distribution grid and detecting phase deviations with the deployment of low cost PMU-Phasor Measurement Units- in selected hot spots of our distribution grid. At the best, this PMUs would be considered as a kind of nervous system of BKW´s future Smart Grid.

This sensory system shall give the LV grid operator a dynamic state estimation of the stability of the distribution network especially in presence of ever increasing decentralized energy production such as PV. Furthermore the measured phasors could be used as building block for new innovative adaptive protection systems in the LV and MV parts of the network.

In order to verify the correctness of this assumptions and the feasibility of building the Smart Grid around a PMU platform a representative portion of our network (see figure 1) with the worst possible conditions with regards to increased voltage levels so as to test the worst scenario such as e.g. transformer overload was selected.

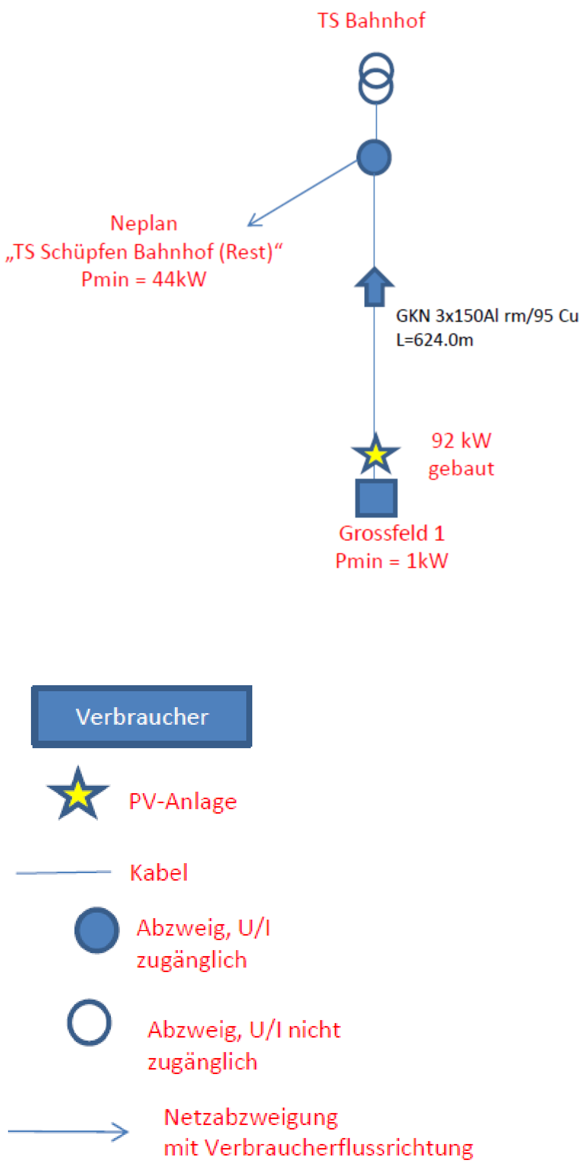

Fig. 1 Network Modelling of the chosen field test region to be used as reference for the validation of the model with the real time phasor measurements

BKW SMART GRID ARCHITECTURE

In order to tackle on a system wide basis the increasing problem of voltage rise due to increased level of intermittent LV-injected decentralized power from PV BKW has defined an architectural framework.

This should support the implemention of a future proof and scalable smart grid ecosystem that can solve that specific problem but also upcoming challenges.

The major components of the BKW smart grid architecture are:

i. STS-Smart Transformation Station: a MV/LV distribution transformer station equipped with a controller/communication gateway, sensing appliances and a data concentrator
ii. EB-Energy Box: a modular device incorporating smart meter, home automation interface and a control mechanism for mitigate voltage uprise due to LV-connected PV
iii. SGA-Smart Grid Applications: specific applications that optimise the operations, utilization of the distribution grid and empower the prosumer (producer and consumer).
iv. Last but not least the right mix of communication technologies plays a very important role as far as latency time, bandwidth and data integrity in order to support the implementation of the SGA.

The phasor measurements would be part of the core platform that would be used to build up the smart grid.

THE PMU AS THE PACEMAKER OF THE SMART GRID ARCHITECTURE

The PMU functionality can be used to ensure grid stability, reliability and optimal utilization at all time in the very same way as a natural pacemaker is doing it in the human blood circuit.

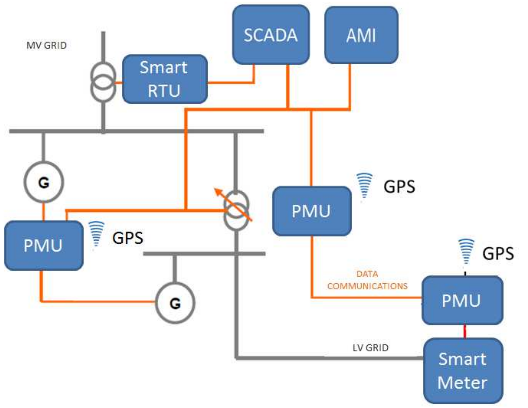

Fig.2 PMU as part of the BKW Smart Grid Architecture

SMART GRID APPLICATIONS USING PMU

Many potential applications of PMU in transmission networks have been documented in [1].
In a LV distribution grid, the following applications could actually be covered by the coordinated use of real time phasor measurements:

- Dynamic topology estimation of the LV grid without prior use of network planning information
- Grid health or state estimation (normal, N-1, stressed)
- Grid stability management
- Power quality
- Inverter parameters management (VAR and active power set points, etc…) for congestion management
- FLISR (Fault Location Isolation and System Restoration) with special emphasis on system restoration, black start and islanding mode of micro grids.

Last but not least, in case of economic viability the PMU system could be used as a low cost real time monitoring and control system for the distribution grid.

NEXT STEPS

The first phase of the project (field test) has been successfully accomplished. The expected accuracy could be proven at the field test measurements.

Next steps will be to install additional PMU devices in the LV and MV network.

The project phases are listed below:

- Field test of demonstrator equipment (done)
- Pilot test covering a subset of BKW LV and MV network (approximately 5-10 STS)
- Design and evaluation of the appropriate communication infrastructure to support the smart grid applications using PMU
- Design and evaluation of a network management system
- Design and implementation of the smart grid applications using PMU

CONCLUSIONS

The field test performed in a rural part of the BKW LV grid demonstrated that synchronous phasor measurements can be used to selectively nail down the hot spots or areas where unbalance problems or stressed situations can expected. The tests also proved that there is a good likelihood to be able to perform predictive maintenance of primary equipment such as transformer or circuit breakers by using the signatures of the phasors.
The next phase of the project will be to test the PMU system in a larger representative part of the BKW grid.
Furthermore we would like to implement local distributed intelligence (in form of a software agent) to the smart grid devices which mediates with a centrally located platform (e.g. a PDC-Phasor Data Concentrator in the backend IT infrastructure) in co-operation with the SCADA system.
The ability of the smart grid devices to be as flexible as possible (similar to a JVM-Java Virtual Machine or distributed middleware) in docking into different vendors' EB and STS is going to be key (see [2] for several examples).
By being vendor's agnostic we can guarantee interoperability, an optimal cost per function and therefore aim at an overall maximum ROI on the whole smart grid platform.

REFERENCES

[1] A.G. Phadke and J.S. Thorp, 2010, Synchronized Phasor Measurements and Their Applications, Springer, USA.

[2] David S. Evans, Andrei Hagiu, Richard Schmalensee, 2008, Invisible Engines – How Software Platforms Drive Innovation and Transform Industries, The MIT Press, USA.