BENEFITS OF SYNCHROPHASOR SOLUTIONS FOR DISTRIBUTION NETWORKS

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ABSTRACT

The electricity transmission and distribution grids are operated more and more closer to the stability limit. Changes in the last years are caused by increasing infeed of renewable energy, increasing energy trade and the trend to interconnect neighboured grids. Resulting is a shift from static behaviour to more dynamic processes to happen in the transmission and distribution grids. This raises requirements to the control centers which have to be able to monitor the dynamic processes in realtime. Realtime monitoring is the prerequisite to react on time.

Measurements from Phasor Measurement Units (PMUs) fullfil the requirements to a real-time monitoring source for network stability analysis. The time-stamped phasor measurements allow a view to the dynamic processes which is of a great additional value compared to standard RTU measurements of RMS values.

The paper discusses an actual system for wide area monitoring with synchrophasors from PMU. It focuses on applications like power swing recognition, island state detection and monitoring of transmission corridors. An outlook to future wide area control systems is given.

Finally, the paper gives an overview on the current status of standardization of IEEE C37.118 and IEC61850-90-5. These two standards are the leading standards for PMUs, PMU communication and PDCs and currently are undergoing fundamental innovation.

INTRODUCTION

Possible Applications of Wide Area Monitoring with Synchrophasors are shown in Fig. 1 (taken from /1/). The applications are clustered by timeline, deployment challenge and possible benefit and impact. The following applications are useful also in the area of distribution networks:

- Angle/Frequency Monitoring
- Post-Mortem-Analysis
- Voltage Stability Monitoring
- Improved State Estimation
- DG / IPP Applications
- Power System Restoration

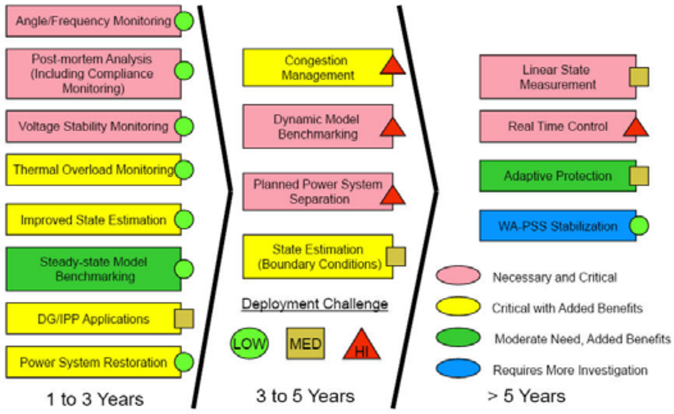

Fig. 1: Possible Applications of Wide Area Monitoring

APPLICATION OF SYNCHROPHASORS IN DISTRIBUTION NETWORKS

This chapter discusses the applications listed in the introduction with respect to their application in distribution networks.

Angle/Frequency-Monitoring

Using PMU measurements for Angle- and Frequency-Monitoring is a general step to enhance the observability of electric networks. This is useful also in an increasing number of distribution networks because the trend shows they take over more tasks that have been reserved to transmission networks. Therefore more dynamic comes into the distribution network caused by fluctuating renewable generation (wind, photovoltaic). The continous measuring of the synchrophasors in such a distribution system supports the understanding of the dynamic behaviour. It can be used to determine the power balance in a distribution network.

Post-Mortem-Analysis

In case of the need for analysis after a fault, the recorded synchrophasor measurements are very valuable. With these “flight recorder data” available, a quick evaluation of the facts can be performed. Intelligent user interfaces enable the operator to quickly find the cause and sequences of the disturbance. Also the documentation of the event for example on request of authorities is possible in a fast and easy way. This application is valuable also for use in distribution networks.

Voltage Stability Monitoring

Voltage Stability Monitoring is one of the standard applications for Synchrophasor Measurements. In transmission systems, this application monitors the load of a transmission line or corridor, using PMU measurements on both ends. In distribution systems, there are normally no explicit transmission corridors. However, monitoring of the dynamics of the voltages gives a good picture of the reactive power flow.

Improved State Estimation

Synchrophasor Measurements can contribute to State Estimation by feeding in additional fast measurements. This can improve speed and accuracy of the state estimation. In [2], the principle is explained. Another benefit is that by using PMU-Measurements for State Estimation, less measuring points are required because of the time synchronization of the measurements. This makes it an affordable alternative for distribution systems, especially if no other measurements exist (greenfield approach).

DG / IPP Applications

Distributed Generation (DG) and Independent Power Producers (IPP) are connected to the distribution level in majority. Since there is a significant part of this energy sources coming from renewables (wind, solar), these sources are of dynamic behaviour. For network stability analysis and balancing of energy flow, PMU measurements can make important contributions, see the chapter "Example: Use of Synchrophasors for energy accounting". First applications which use the PMU measurements for control of generation units on distribution level are also being developed.

Power System Restoration

In case of a partial or complete separation of a supply area, the synchrophasor measurements can help for a quick reconnection. They give the necessary information for the reclosure of the circuit breakers by showing the situation of frequency, phase angles, voltage and current measurements. This has been experienced successfully for example after the Florida blackout in 2008, but can be transferred also to the application area of distribution systems.

EXAMPLE: USE OF SYNCHROPHASORS FOR ENERGY ACCOUNTING

In this chapter, an example for application of PMU measurements in a distribution network with the goal of energy accounting is presented and discussed. The project "RegModHarz" ([3], [4]) is applied to a region "Harz" in Germany. The goal is to group all local decentralized power generation into one virtual power plant and to control the loads where possible so that the region can operate without additional power flow from outside (see Fig. 2).

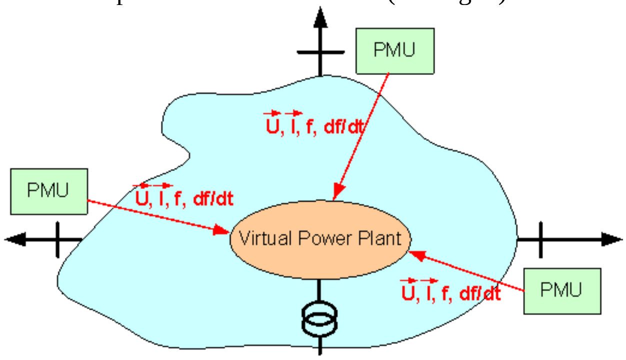

Fig. 2: System configuration in project "RegModHarz"

The PMUs are placed at the border connections of the regional grid with the surrounding electrical network. They deliver their measurements to the central component "Virtual Power Plant" which coordinates the generation and the controllable loads. The achieved benefits include:

- High precicion in energy accounting
- Coordination of generation and consumption
- Higher reliability for decision-making
- Delivering a data base for services like energy market

The region has available 250 MW wind power, 80 MW pump storage and 12 MW thermal/electric power station. Controllable load includes 10 MW in industry and 0,5 MW in households. The virtual power plant coordinates in the best possible way the power balance between these components. There are three different operating modes possible:

- Maximising renewable generation
- Cut-off load peaks
- Maximising network stability

This project delivers reports ([3]); it is still under progress.

REALIZATION OF A WIDE AREA MONITORING SYSTEM

In this chapter, a realization example for a wide area monitoring system is shown to discuss requirements to such a system. The system is applicable to both transmission and distribution systems.

Fig. 3 shows the structure of the Siemens Wide Area Monitoring System "SIGUARD Phasor Data Processor" (PDP). The SIGUARD PDP server receives the synchrophasor measurement streams from the PMUs via the IEEE C37.118 protocol.

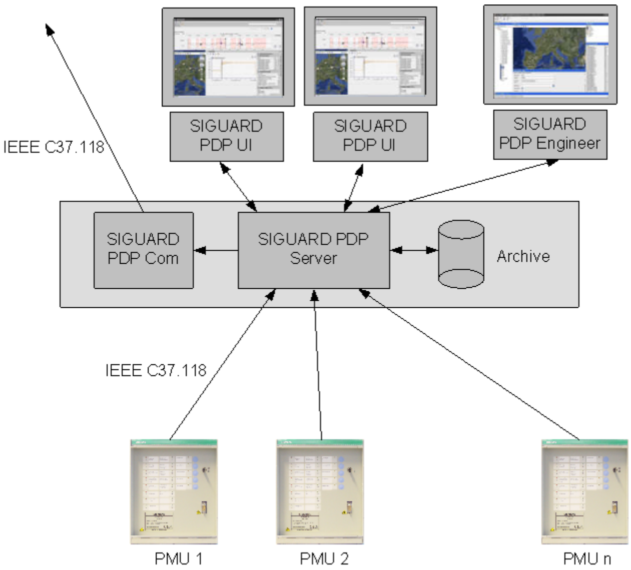

Fig. 3: Structure of a wide area monitoring system

The server distributes the measurements to the user interfaces (UI) which are usually installed on separate computers. The server computer (including also the archive) is located in a secure environment to ensure safe permanent operation. The component "SIGUARD PDP Com" provides communication to other Wide Area Monitoring systems, it behaves at the interface like a PMU, using the same protocol IEEE C37.118. Nevertheless, the operator of the SIGUARD system can of course determine which measurements shall be transmitted (for example voltage phasors and frequency) and which not (for example current phasors). The components Server, Archive and Com form together the Phasor Data Concentrator (PDC) which can operate separately. The abbreviation "PDC" is frequently used in documents describing wide area monitoring.
The User Interfaces are placed in the control center rooms. The SIGUARD Engineer is used for configuration of PMUs, applications, communications, calculations and graphics. Change of configuration like adding one PMU is a task that can be performed intuitively.
The User Interface (Fig. 4) is designed to give a transparent view to the network dynamics. The power system status curve on top of the screen is an artificial value which indicates the distance to critical status of the monitored system. It is calculated from the distances of all measurements from their limits. It has the function of a trafficlight, but additionally shows the tendency of the state of the system.

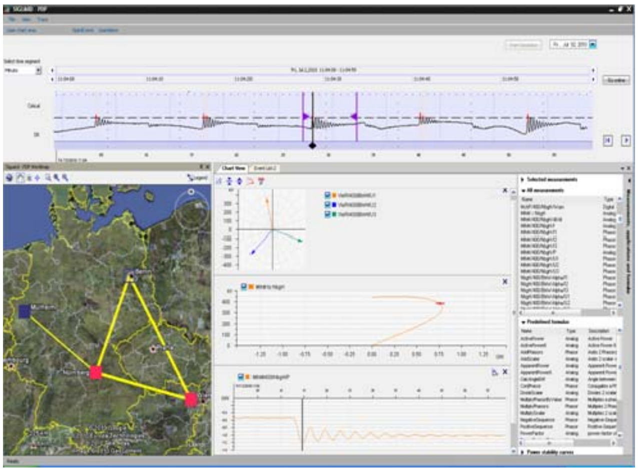

Fig. 4: Typical User Interface of SIGUARD PDP

Fig. 4 shows the principle of the application "Island State Detection". With the continous measurement of the frequencies, it is possible to recocgnise immediately if network split occurs. If for example the two lines at the right side in Fig. 4 would be interrupted simultaneously, two isolated areas would occur. This will be indicated automatically by the SIGUARD PDP system, using alarm indications. Such an interruption took place on Nov 4 2006 in the European transmission system; it was not clearly seen by all participants immediately.

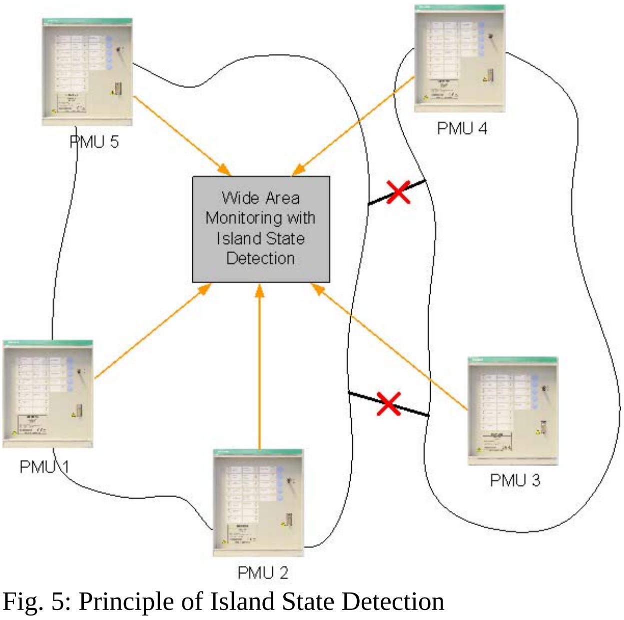

Fig. 5: Principle of Island State Detection

The Island State Detection uses the availability of the fast measurement streams from the PMUs; it does not need the Phasor Values of Currents and Voltages.

ACTUAL STATUS OF STANDARDIZATION

The current widely used standard IEEE C37.118 (2005) in its actual version describes the communication interface for PMU data. It is available in nearly all currently offered PMU products and Wide Area Monitoring systems and has been proved to be a well applicable solution.
New standardization developments are under way in two directions:
1st direction: Split of the IEEE C37.118 into two parts.
IEEE C37.118.1 as the standard for performance requirements to dynamic phasor measurement behaviour and dynamic frequency measurement of PMUs. This issue has been found to be crucial for the accuracy of PMUs which are designated to improve the dynamic measurements of the network. Additionally, details for testing and calibrations of PMUs will be contained.
IEEE C37.118.2 as the communication standard which takes over the content of the former IEEE C37.118. Its goal is to be compatible with existing IEEE C37.118 implementations, so only few improvements will be contained.
The time horizon for this will be a release in 2011.

2nd direction: Creation of an IEC-standard for synchrophasors. This standard will be named IEC61850-90-5. The communication will be using the means of IEC61850, whereas the content of the new IEEE C37.118.1 will be contained in this standard using the "dual logo" principle. This new IEC standard will also deal with new applications like adaptive relaying or wide area controls. It also discusses security models. A migration path from IEEE C37.118 (2005) to an IEC61850-90-5 solution is shown. Nevertheless, after release of this standard, PMUs and PDCs will probably offer both communication options (IEEE C37.118.2 and/or IEC61850-90-5) because of the large installed base of the IEEE-protocol.
IEC61850-90-5 will take some more time to become international standard (IS).

CONCLUSION

Synchrophasor solutions are being developed and tested in different applications all around the world in both areas transmission and distribution. This paper points out the most useful applications for power distribution. One example is shown which is supported by the federal government of Germany.
PMUs for distribution applications could be integrated solutions, for example as a configurable functionality of protection devices, to reduce costs.

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