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Experiences and Benefits of Systems for Wide Area Monitoring

Joachim Bertsch
Cedric Carnal
Petr Korba
ABB Ltd.
SWITZERLAND

Michael Ingram
TVA
USA

Lawrence Broski
ABB Inc.
Canada

Walter Sattinger
ETRANS Ltd.
SWITZERLAND

INTRODUCTION

Transmission systems are more and more pushed towards their capacity limits for various reasons. Amongst these, the factors contributing most are a continuous gradual growth in consumption, system extension restrictions due to environmental concerns and the increase in cross-border trading activities. The latter introduces a significant variation of power flow patterns. This means a new challenge for the real-time monitoring of stresses of transmission systems. To serve this purpose, a phasor measurement technology has been proposed in Phadke (1). Due to advances in communication and computation technologie this method has become more feasible.

This paper outlines the contribution of phasor measurement techniques to wide area monitoring and control (WAMC) of power systems. The structure is as follows: First a short description of a commercially available WAMC system and its pilot implementation in a real transmission system is provided. Then some examples of measurement results and a brief analysis of a measurement campaign are presented. Possible future extensions and applications are discussed in the last section.

IMPLEMENTATION AND SYSTEM PLATFORM

Phasor Measurement Units (PMU) allow the time synchronization of the measurements with an accuracy of up to 1 microsecond utilizing a satellite Global Positioning System (GPS) signal. Therefore, system dynamics can be monitored regardless of the large geographical distances between the locations of measurement points.

The goal of the pilot application of the WAMC system in the Swiss transmission system was to monitor the impact of heavy power transfers over the north-south axis. Therefore, four PMUs have been placed along this transmission corridor as shown in Figure 1.

These PMUs measure voltage and current phasors and send their data to the System Monitoring Centre (SMC) in intervals of 100 milliseconds (real-time). There these data are stored and can then be processed in various ways. The data (both direct measurements and calculation results for monitoring purpose) are displayed on a user-friendly Graphical User Interface (GUI). The GUI comprises the main view, which can be the single line diagram and/or the functional view of the WAMC system components together with the warning and alarm history window, and a number of displays that appear after clicking on the corresponding components in the main view. The faceplates contain for example trend displays, algorithm outputs, etc.

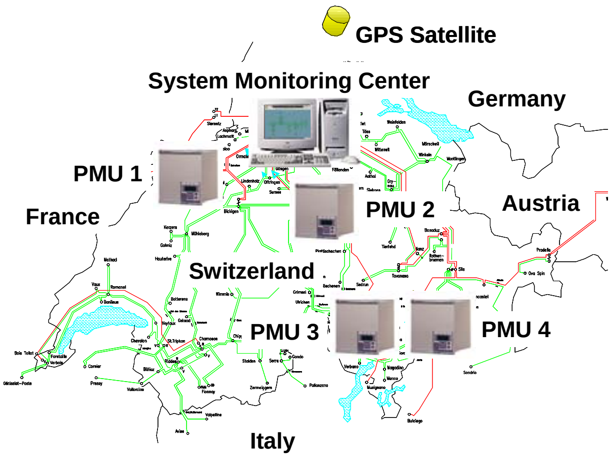

Fig. 1: Locations of the PMUs installed in the Swiss transmission system.

MEASUREMENT RESULTS

The data collection period has started before the winter peak 2003 and is still ongoing. The identified usage of data from the existing setup can be divided into two categories: power system operation and power system planning.

System Operation

The difference in voltage phase angles across the Swiss transmission system proves to be a very good indication of the stress of the transmission system caused by the power export to the south as shown in Figure 2. There is an almost linear relationship between the transferred power and the voltage phase angle difference. Thus both ends of a line are supervised with PMUs, the line losses and impedance can be computed very precisely. From these, an average line temperature can be derived, as shown in Figure 3. This is usually referred to as a dynamic thermal rating – Raniga (2).

The two mentioned applications used could serve as a great decision support both in case of normal operating conditions and in emergency situations.

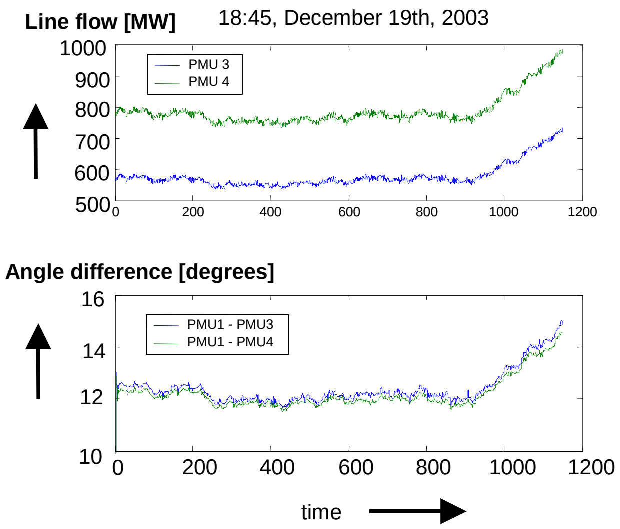

Fig. 2: An active power transfer via two monitored lines and its relation to the voltage phase angle difference across the Swiss transmission system.

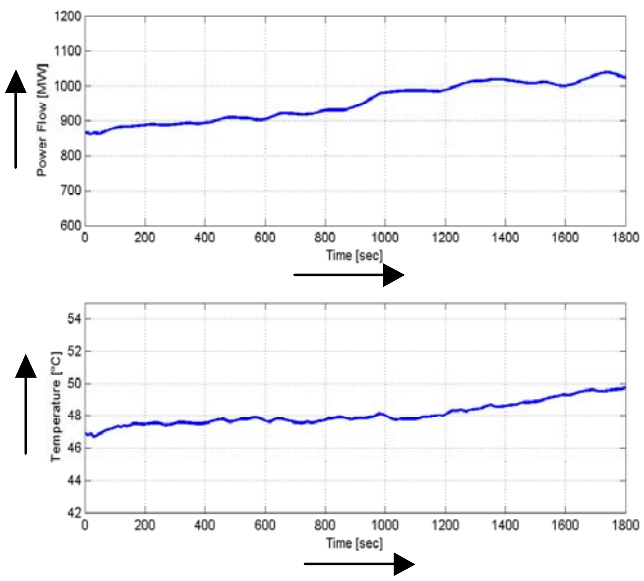

Fig. 3: Results of line thermal monitoring. The average temperature of the conductor increases from 46 to 49 degrees Celsius as a consequence of the increase in power transfer by 200 MW within a time span of 30 minutes.

System Planning

Phasor measurement recordings can very well be utilized for off-line processing, too. They serve as an input for calibration and verification of the dynamic models of components of the transmission system, especially power plant controllers' responses. The potential for observing transmission system-wide dynamics can be utilized for the analysis of behaviour of the transmission system and the identification of specific properties of the transmission system when planning transmission system's reinforcements and extensions. For these purposes, data can be exported from the platform in a comma-separated value format and are readable easily in Excel for example.

ADDITIONAL APPLICATIONS

The presented installation can be further extended to address more system-wide stability issues. There are research and development activities ongoing, both on the utility's and the WAMC system supplier's side, which are related to the stability assessment based on phasor measurements.

As already mentioned, phasor measurements can be used for the state estimation procedure, which offers a number of advantages over a traditional one. Since the measured quantities are voltage and current phasors, linear expressions can be formulated, thus avoiding numerical problems with a convergence. For further details please see Rehtanz (3). In addition, PMUs can be placed in the transmission system in such a way that their data serve as an additional basis for topology detection (i.e. status of the lines etc.).

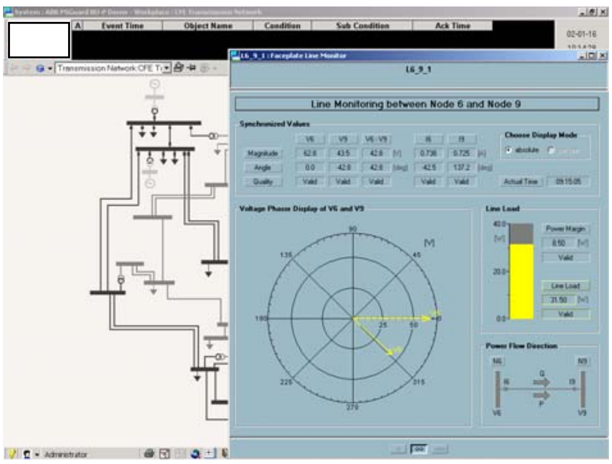

Fig. 4: Example of the Graphical User Interface of the Wide Area Monitoring system. A line monitoring faceplate overlaps the main view with the single line diagram. The yellow colouring of the bar on the faceplate indicates an alert state. The black area in the top part is used to list issued alarms.

In the first stage, the WAMC systems can be used only for monitoring of the condition of the transmission system with respect to stability. The alarms and indicators can help an operator to execute corrective actions, see Figure 4. Voltage instability caused by a gradual load increase may be identified early by employing a PV-curve visualisation, as shown in Figure 5. However, some phenomena are too fast by nature to be handled with human involvement. Therefore, future control features become more important. Today, this functionality is dedicated to Special Protection Schemes (SPS), which are a set of local protection relays coordinated via simple rules that are defined in off-line pre-studies, Anderson (4). One deficiency of this approach is obvious: there is a vast range of actual operating conditions and it is very difficult to account for all of them with a set of fixed rules. Current transmission system conditions should be reflected both in the assessment stage and the selection of optimal control actions, in order to react to a dangerous state most effectively. Therefore, we propose that on-line or even real-time procedures should be employed.

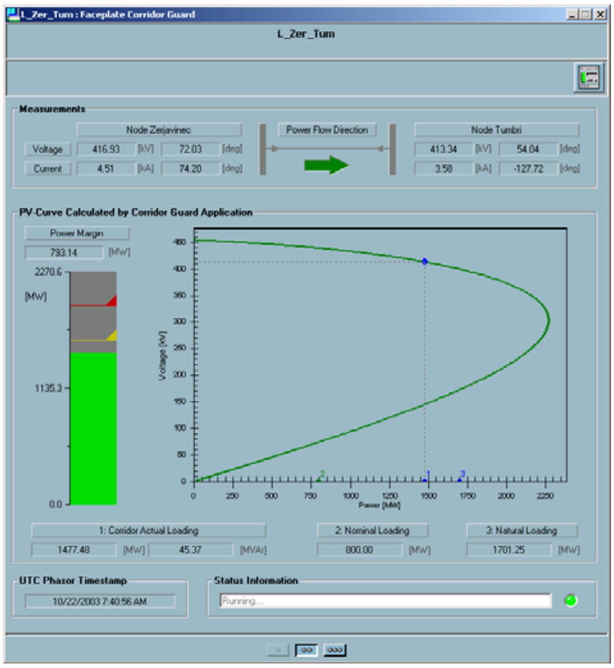

Fig. 5: Graphical User Interface example of the voltage instability assessment algorithm. A PV-curve is used to express the distance of the actual load to the point of the maximum loadability.

Voltage instability driven by a contingency can be mitigated using a method described in Zima (5) that focuses on the emergency condition aspects. Phasor measurements appear to be the most suitable signals bearing information needed for the identification of power oscillation modes in power systems. This topic is explored in Korba (6) and Kamwa (7).

Conclusion

We have briefly summarized the experience with the installation of the WAMC system in the Swiss transmission system. We are convinced that WAMC systems based on the phasor measurement technology have a big potential for application in various fields of power system operation. The main focus is on transmission system security, which is an extremely important issue in the frequently varying stress patterns of power systems.

ACKNOWLEDGEMENT

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