ADVANCED APPLICATIONS OF WAMS

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ABSTRACT

The Wide Area Monitoring Systems (WAMS) allow the realization of new and advanced functions for support of the development and control of transmission and distribution networks, namely the evaluation of network stability, ampacity of lines and detection of critical network conditions. The WAM systems are based on the measurement of voltage and current synchrophasors by the means of PMU (Phasor Measurement Unit) devices. The AIS company deals with the measurement of synchrophasors since 2000 [1].

INTRODUCTION

A part of 110kV CEZ Distribution network was chosen to install and test the WAMS system. The implementation of the WAMS system started in 2009 and its full operation in 2010.
The WAMS METEL complex system by AIS Company includes advanced comprehensive solutions of the following WAMS levels:

- The PMU devices for the measurement of voltage and current synchrophasors (SF) as substations.
- The PDC (Phasor Data Concentrator) and WAMS Central Station devices for the real-time processing and data archiving including a number of analytical and expert functions.
- The Client software for interactive work in all user levels.

All levels of the system operate continuously. The basic and also advanced applications have been implemented and tested with a focus on the evaluation of the network stability and on-line monitoring of the ampacity of several lines.

OPERATION EVALUATION

During almost two-year operation, the WAMS system was verified and tested for robustness, service life and reliability of all parts of the system and also for the correct functionality of the above mentioned system functions. In the next section of the article we will describe some results concerning the behavior of the transmission network in the European context and monitoring of the line parameters and ampacity.

Monitoring of the frequency and power oscillations between network areas

Monitoring of the frequency and power oscillations is an advanced function providing the following benefits:

- warning on the exceeding of protection current limit,
- warning on the exceeding of stability limits given by angle differences.

The function provides the following outputs:

- Alarm generated when an inter-area oscillations exceeding the set limit.
- Monitoring of the oscillation amplitude and damping.
- Warning before the exceeding of limits for current protections.
- Warning before the exceeding of limits of angle differences.

The example from 24 February 2011 can illustrate the usefulness of monitoring the frequency oscillations. Temporary frequency oscillations appeared in the transmission route between Kassoe (Denmark) and Brindisi (Italy). The entire phenomenon took about a quarter of an hour and was captured by PMUs installed within the WAMS system.

The PMUs captured the whole phenomenon with sufficient relevance regardless of the fact that they were not connected directly to the transmission network. The following figures show the results of PMU data analysis and also comparison with the data available from public sources.

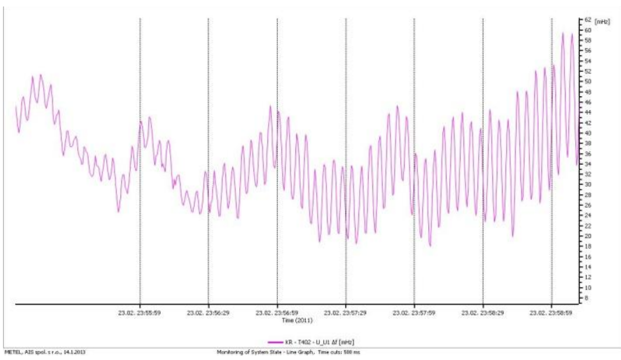

Figure 1 - Event 24.2.2011, frequency oscillations captured in CZ

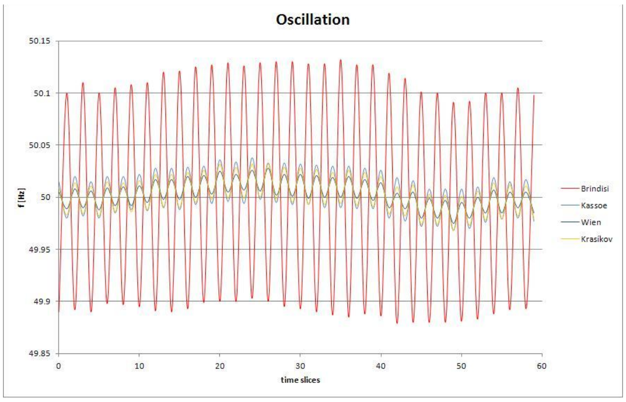

Figure 2 - Event 24.2.2011: comparison of frequency oscillations obtained from various sources

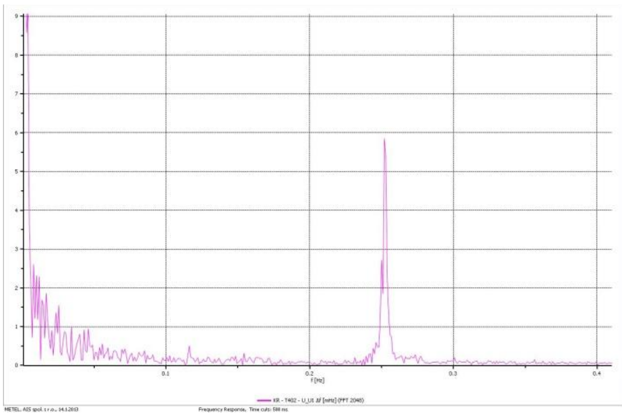

Figure 3 - Event 24.2.2011: spectral analysis of frequency oscillations captured in CZ

On-line monitoring of line parameters

The on-line monitoring of line parameters is an advanced function based on the assumption that line parameters are not static values. The line parameters are affected by the line load, weather conditions, aging etc. The on-line calculation of line parameters also has to take into consideration the influence of measurement error in current and voltage instrument transformers. A possible error of estimation can be further reduced by the use of causal relationship between quantities.

The minimal requirement for the on-line monitoring of line parameters is the measurement of voltage and current synchrophasors in both line ends. Further measurements in nodes associated with the line can improve the calculation.

The actual line parameters are characterized e.g. by

- The series resistance representing the average line temperature.
- The shunt conductance is a measure of the line quality; it shows losses caused by leakage. The shunt conductance increases with the line age and it is also dependent on the weather conditions, namely on humidity.
- The reactance and capacity are predominantly constant values given by the line geometry.

The following figure shows an example of line resistance calculation based on the operational data captured by the WAMS system.

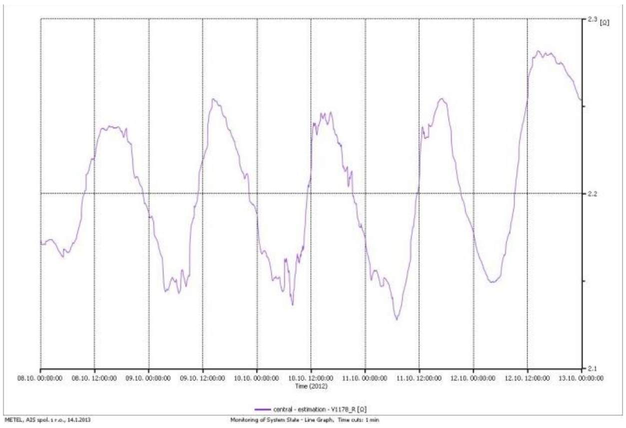

Figure 4 - Graph of line resistance in 5 days

On-line evaluation of ampacity

The line ampacity is represented by the highest current that will not disrupt technical and safety limits. The ampacity is limited e.g. by ranges of measurement devices, the cross-section of critical places of the line (joints, bypasses) or the safe height of the line conductors above houses and other objects defined by standards [2].

The most significant limiting factor of the line ampacity is the line temperature. The evaluation of line ampacity is based on the calculation of line resistance and consequent evaluation of the line temperature. The limit of line load is variable and its average value is about 20 to 30% higher than the commonly used static limit.

Benefits of the line ampacity evaluation

- The higher permitted load limit used for contingency analysis indicates the reserve in the use of power networks.
- The use of higher line capacity particularly in the winter season.
- The saving of investments in the building of new lines.
- The use of full line ampacity in solving critical and emergency situations.

The used load limit is determined by critical operational conditions, which are usually:

- maximum allowed line temperature 80˚C,
- ambient temperature 40˚C,
- wind speed max. 0.5 m/s.

The figure 5 shows the weather conditions in the area near the substation Vítkov in 2010. It can be seen that the critical conditions did not appear and the conditions near the critical values appeared only rarely.

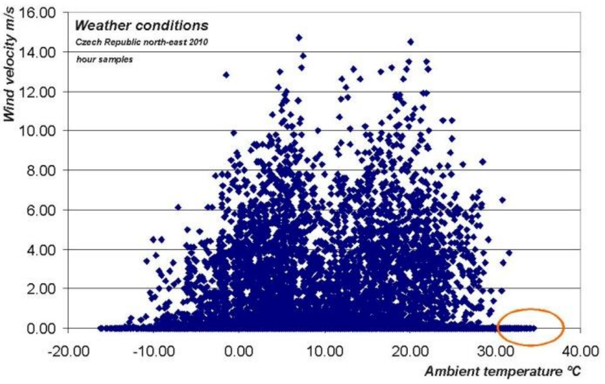

Figure 5 - Weather conditions in 2010

The distance between the operational conditions and critical weather conditions leads to the fact that the line temperature is significantly lower than the stated limit of 80˚C, even in the cases of line load.

The actual average line temperature is determined using the series line resistance. The difference between allowed limit and actual line temperature is used for the determination of a current that causes warming of the line up to 80˚C. Such current represents the fund between actual line ampacity and actual current.

The following graphs show the ampacity, actual line load and a potential reserve within one year.

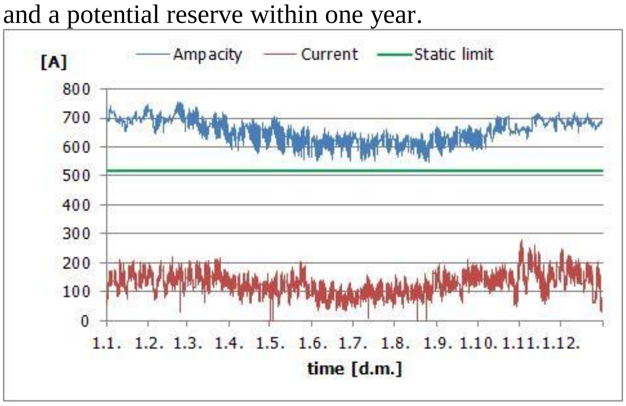

Figure 6 - Line current and calculation of ampacity in one year

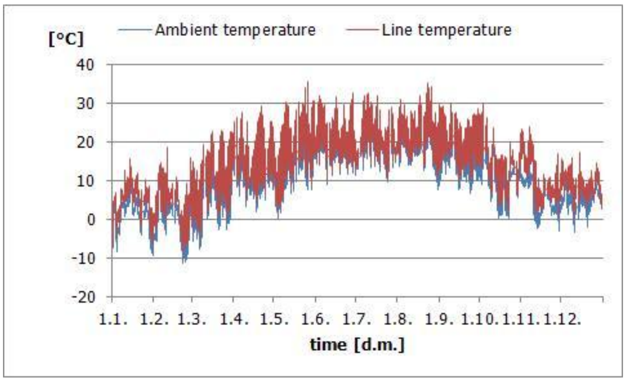

Figure 7 – Calculation of line temperature in one year

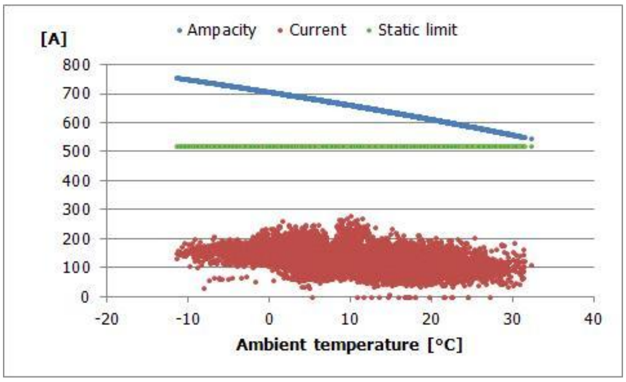

Figure 8 - Line utilization and ampacity

Island operation

The detection of the island operation is an advanced function based on the continuous monitoring of frequency in all voltage nodes and detection of separation of some network parts – island operation. The WAMS system also provides support for the reconnection of separated part back to the network. Thus the WAMS system allows the supervision of network integrity and remote control of the synchronization process.

The following figure shows the operation and synchronization of separated part of 110kV network.

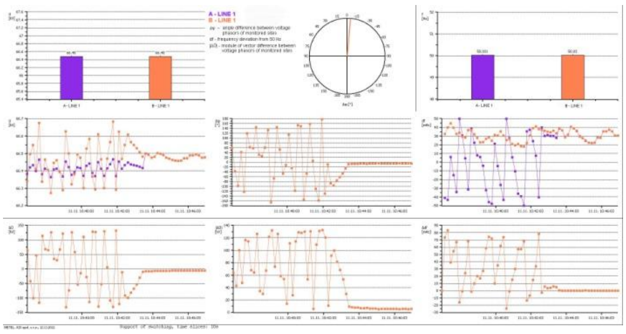

Figure 9 – WAMS system support for detection of island operation

CONCLUSION

The WAMS system operating in the part 110kV network verified the usability of advanced functions based on the measurement of synchrophasors. A correctly designed complex WAM system brings significant benefits in the improvement of operation, security and stability of network. The measured data are used for further development, methodology and verification of synchrophasor-based functions.

The development of WAMS system took place and the results stated above were achieved within the project supported by the Ministry of Industry and Trade of the Czech Republic.

REFERENCES

[1] Václav Böhm, Antonín Popelka, Bohumil Sadecký, 2005, "Synchronous measurement in electrical networks", *CIRED*, Torino

[2] Antonín Popelka, Daniel Juřík, Petr Marvan, 2011, "Actual line ampacity rating using PMU", *CIRED*, Frankfurt