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Use of WAMS for Stable Power Transfer Assurance Across the Slovenian Grid

U. GABRIJEL*, P. OMAHEN, U. SALOBIR
ELES d.o.o
Slovenia

SUMMARY

The deregulation of the energy-supply industry led to more intensive use of transmission grids not foreseen at the design stage as today trading activities on grids are performed in larger extent over longer distances. To ensure a proper level of power system security in these strained operational conditions where even a simple incident can escalate very rapidly into a large scale breakdown, the TSO's will need to apply any available and required measure. In highly meshed system frequently under stress it is essential that assessment of stability limits is done precisely and without fail.

In the real time operation wide area monitoring (WAM) becomes increasingly recognizable technology that supports system operators' decision making aimed to ensure reliability and security margins continuously by early warning of potential network stresses.

This paper gives an insight into ELES' efforts to maintain the security of supply in region. Firstly, the importance of stability issue with respect to high physical transits via Slovenian power system is emphasized and confirmed with numerical calculations. Secondly, the ELES' WAM-system project in terms of elaborated planning and establishment is presented. Preliminary findings from test operation, future enhancement and an evolution road-map are also presented.

KEYWORDS

Power system stability, WAMS, deregulation

uros.gabrijel@eles.si

1. INTRODUCTION

The deregulation of electric power industry in Europe has put more stress to transmission system operators (TSOs) because today cross-border transmission lines that were primarily designed for sharing power reserves, ensuring better frequency response and trading in small extent, have to bear physical flows resulting from long-distance trades over a large part of the continent. A lack of global coordination in transfer capacities assessment within the UCTE results in loop-flows producing congestions that often can-not be mitigated by a TSO leaning solely to its own resources especially ones operating smaller systems. A unified market emphasized in Green Paper on energy recently issued by the European Commission [1] relies also on long-distance trade of electricity which today origins mainly from eastern countries still holding considerable amounts of cheap power from not so environmentally restricted electric power plants equipped with old technologies. Yet another problem for TSOs evolves from global traders' portfolio optimization, namely, large control blocks' hourly program changes in UCTE results in rapid change of flow patterns making predictions really difficult. Having in mind the unbundling and lack of TSOs' control over unit engagement this also ends in substantial frequency deviations sometimes. Trying to leave the economics apart, unsuccessfully, TSOs have to cope with decreased operation safety margins where the open market environment tagged many information that are vital to secure system operation as market sensible and thence confidential. Standing on the neutral ground one can say that while forcing the market liberalization regulatory bodies failed to prepare friendly environment for TSOs in time.

What we have learned from recent blackouts (Italy, Sweden, USA - 2003) is that the utmost important role play fast and correct information on system state. Comprehensible information in due time properly interpreted by the operators or the advanced controllers are the key to a reliable and economically successful system control. Wide Area Measurement System (WAMS) is one of such emerging systems that enable TSOs better understanding of system behavior and look even beyond their horizon which is crucial from the reasons mentioned above. With its ability to synchronize phasors from geographically dispersed measuring points WAMS can partially fill the gap of inadequate level of coordination between neighboring TSOs. Systems tend to be more prone to instabilities if they experience large amounts of power transfer because of decreased safety margins. A question of stability starts to limit the transfer capacities.

This paper is organized as follows. Section 2 provides ELES efforts to maintain the security of supply in region in the stressed conditions of large power transfers in terms of security margin assessment via simulations. Advantages of WAMS system, roadmap of implementation and some recordings from test operation of WAM system is presented in the section 3, while a comparative analysis on available EMS/SCADA functions in control room is presented in section 4. A conclusion follows in the last section.

2. SECURITY MARGIN ASSESSMENT

Slovenian power system is often heavily loaded due to its geographical position between regions of high Italian import and high production in east and east-south Europe. These transit flows reach up to 1800 MW in last year. Figure 1 shows the discrepancies between scheduled (commercial) flows and physical flows. It is evident that the ratio of 1:3 to 1:4 is not exemption. Yielding from this high transit flows emerged after the reconnection of the IInd synchronous zone in October 2004 ELES assigned an extensive study to the

Electroinstitute Milan Vidmar in Ljubljana to perform dynamic simulations to assess the stability margins.

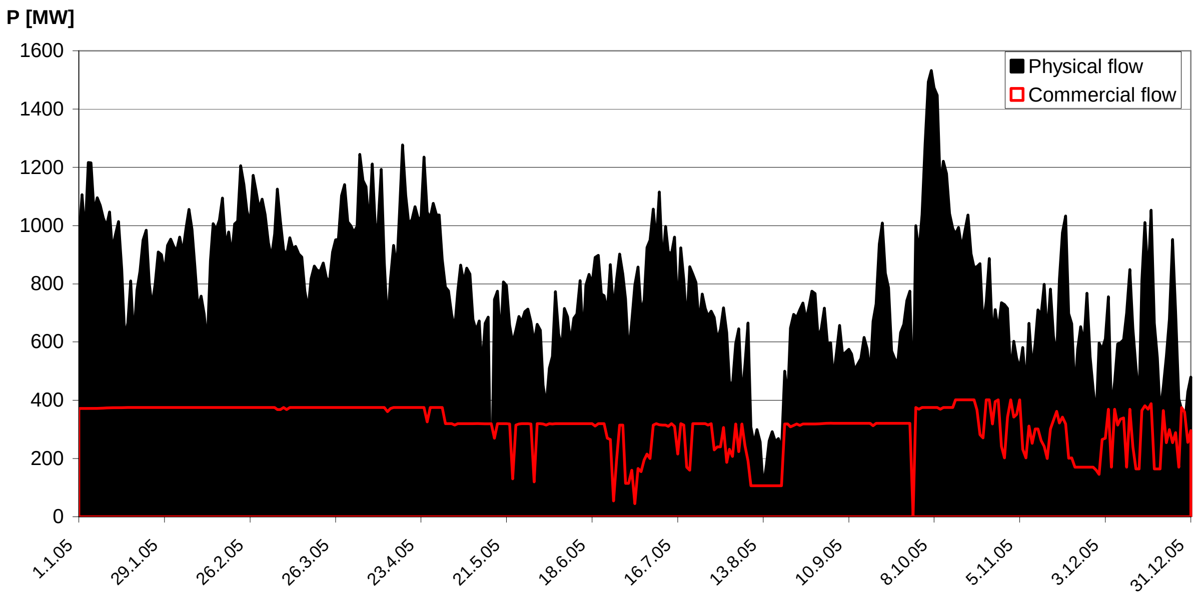

Figure 1: Houry measured flows between Slovenia and Italy vs. commercial exchanges

Simulations showed that there is transit flow across the Slovenian network hit the stability limit around 1700 MW [2]. In order to explain the phenomena two figures are presented, Figure 2 shows a transient phenomena following Slovenia-Italy tie-line outage at 1000 MW.

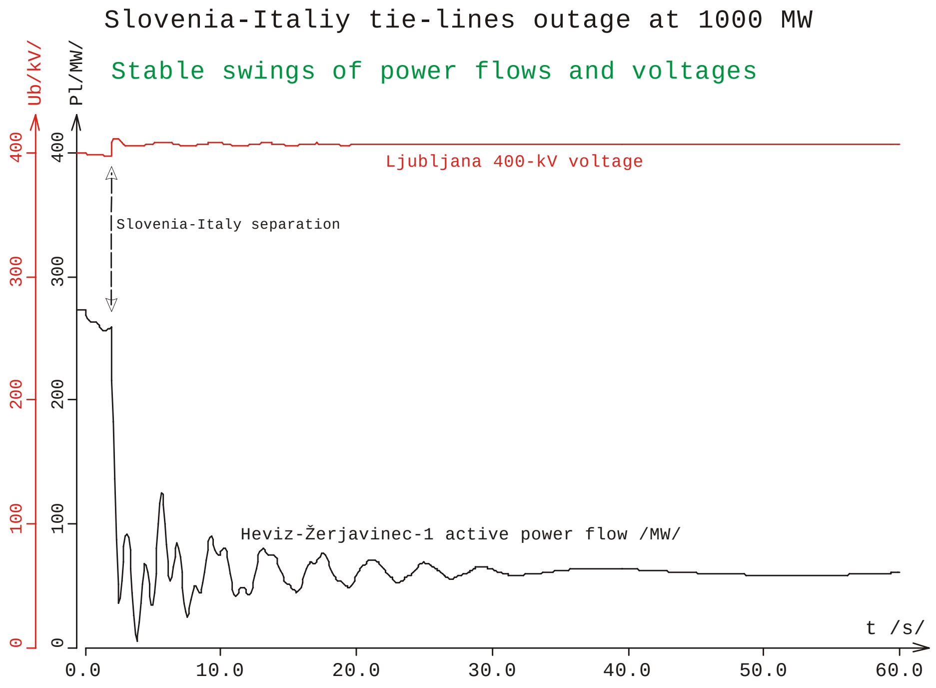

Figure 2: Transients after disconnection of SI/IT tie-lines at 1000 MW

The oscillations are well damped, transit from Hungary via Croatia decreases by magnitude of 3 and the voltage in the center of Slovenia increases since lines consume less reactive power with transits cut.

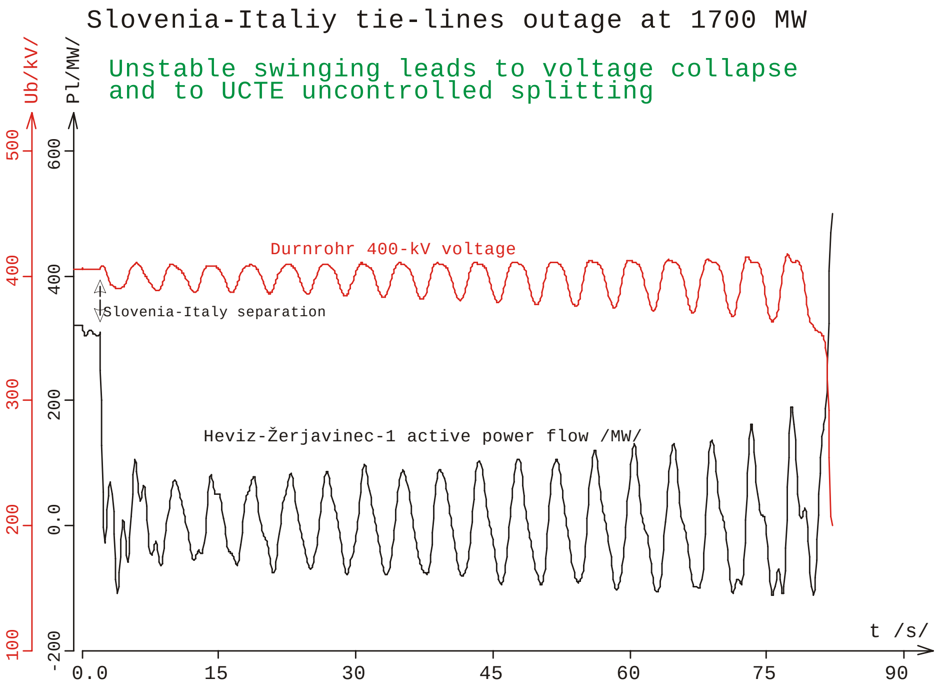

Figure 3: Transients after disconnection of SI/IT tie-lines at 1700 MW

The same event, however, triggered at the transit flow around 1700 MW evokes extremely dangerous system behavior (Figure 3) ending up in splitting the UCTE network into a stable and unstable part. Since the neighboring Austrian network is rather weak, alternative route for the power initially flowing via Croatia, Hungary, Slovakia, Czech Republic, Germany and Swiss to Italy is prolonged and two possible modes of system separation were identified as shown in Figure 4.

Figure 4: Modes of separation

Though several power plants in the region use power system stabilizers, un-damped power system oscillations eventually lead to a power system collapse.

Results from an extensive research on the security of energy transit flows via Slovenian power system shows that energy flow limits should be seriously adhered in to order to avoid cases of the kind that took place in 2003 when the Italian power system collapsed. There are several issues yielding from this experience and that call the attention:

- TSOs coordination in order to prevent excessive power transfers (cross-border congestion management)
- Investments in increasing transmission capacities
- Real-time exchange of information (measurements: RTU, PMU,…)

3. WAMS from Slovenian standpoint

3.1. WAMS overview

Conventional systems for monitoring grid performance can provide very limited insight into dynamic situation because they use non-synchronized measurements from remote terminal units (RTUs) that assess RMS values of currents and voltages of a system that is continuously changing its operation point. According to Shannon’s theorem the sampling frequency has to be twice as high as the frequency of the observed phenomena giving us a hint that the traditional Control room’s SCADA systems designs using non-synchronized measurements can only properly deal with slow system perturbations such as tackled by secondary voltage and frequency control. Additionally a state estimation has to be used in order to have a fully coherent picture of system state. Quite oppositely, as already mentioned in the introduction WAMS acquires current, voltage and frequency phasor measurements that are time-synchronized via Global Positioning System (GPS) receivers up to a time resolution of one microsecond. In order to do so WAMS in its essence uses software based data concentrator with the ability to receive, process, store and represent measurements from phase measurement units (PMUs) installed remote in substations via standardized protocol and dedicated technical Wide Area Network.

Presently identified added value of WAMS lies in fields of enhancements of monitoring system steady and dynamic state with early detection of system problems, system protection and control and last but not least in advanced planning process which can eventually eliminate any consequent operation problems.

As Slovenian power system lies between two areas with large price difference it is often stressed by high flows and the benefits from applying WAMS are obvious and essential. One of such fundamental application that yields from highly loaded network is a problem of line putting in service at high voltage angle difference. Because of big generation shift involved in the process of decreasing the angles they have to be precisely and promptly measured.

3.2. State of art

ELES started the WAMS project in 2004 by making a decision to install 5 PMUs in the first stage in different strategic locations i.e. 400 kV substations. In 2005 a contract for purchasing a WAM system was signed with a local vendor. The purchased WAMS contains numerous software-based modules that can roughly be classified as:

- data acquisition and storing (14days FIFO database),
- export of selected data,
- threshold, range and difference violation alarm (event data storage and listing),
- graphic user interface (polar and bar diagram, 2D and 3D trend graph, history player)
- virtual PMU (transmitting of filtered/selected data),
- voltage stability monitor,

- frequency stability monitor,
- power swings monitor,
- line temperature monitor.

The design of WAMS is such that it will serve both to dispatchers in the control room by:

- alarming at violation of critical pre-set margins,
- helping them in easier and faster line recoupling,
- monitoring the dynamic system state,
- understanding system behavior by enabling better observability,
- allowing them to make use of full transmission capacity by monitoring conductors' temperatures.

and to system analysts using recordings for post-mortem analyses and planning purposes.

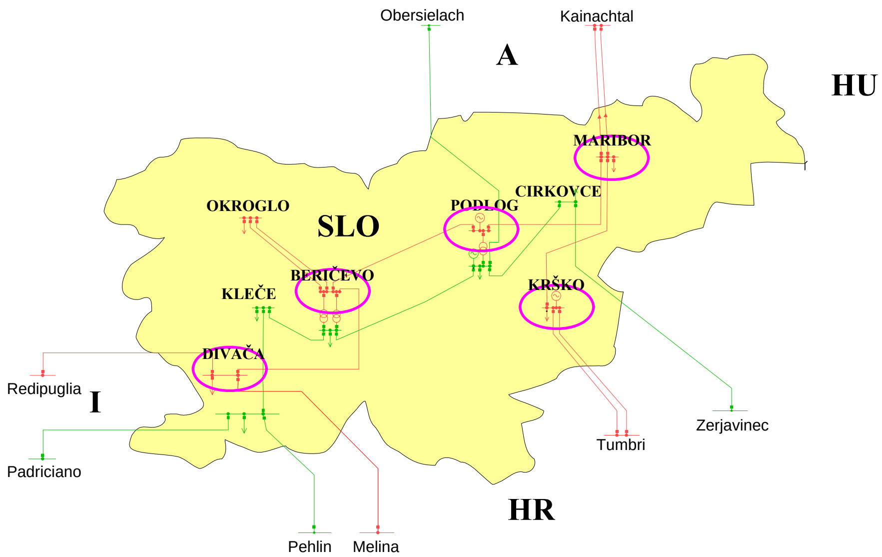

Figure 5: PMUs positions

Presently 2 PMUs are installed, namely in Divaca and Beričevo substations (Figure 5) while the WAM system is still in a testing phase where some modules are not installed yet. Currently, main modules for data acquisition, virtual PMU database and graphical interface with basic features are installed.

3.3. Test operation experiences

Parameterization of event detection logic is not performed yet but the cyclic storage data-base is in the operation for several months now. So, the engineers were able to extract the data of an incident occurred on January 15th 2006 when a permanent single-pole busbar short circuit fault happened in Maribor substation which was followed by a disconnection of all 4 lines by a distance protection relay action. System was operating under N-1 security criterion and no consecutive line tripping took place. Maribor substation has two busbars, however, the system was operating just on one busbar. The operators had some problems in restoration of pre-fault condition system because of several equipment malfunctions and the situation was not clear. A post-mortem analysis of WAMS recordings helped in elimination of possible causes. Figure 6 shows the transients during the unsuccessful recoupling of 400 kV Maribor-Podlog line performed in Maribor recorded in Divaca substation.

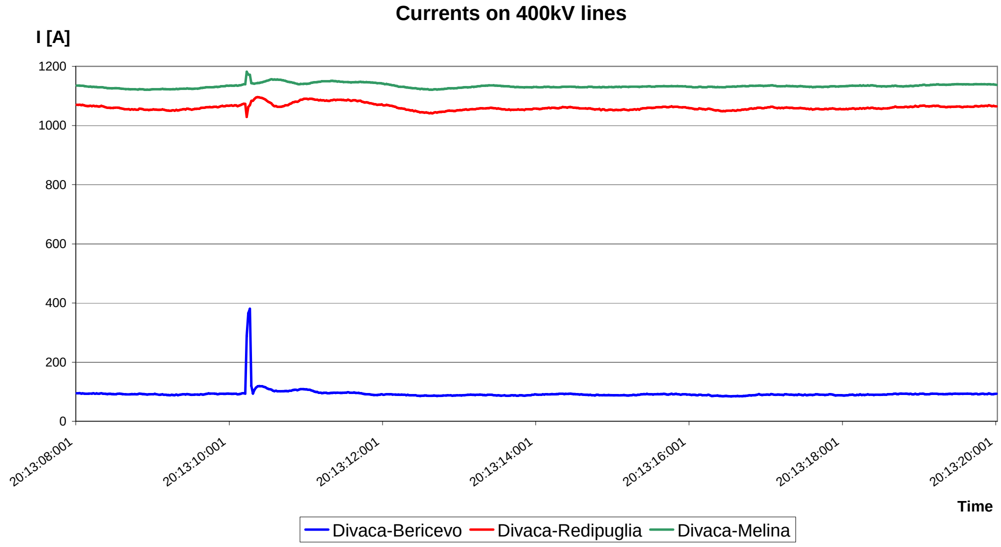

Figure 6: Divaca substation recordings of unsuccessful 400 kV Maribor-Podlog line recoupling

3.4. WAMS future application

The benefits expected from the operation of WAM system are obvious; however, the hard work is yet to be done in order to exploit WAMS full potential. We had primarily assessed following possible further applications:

- improvement of state estimator performance – in near future,
- dynamic models tuning,
- identification and implementation of possible advanced protection schemes.

4. WAMS on-line vs. WAMS off-line and existing EMS functions

Costs of the new age WAM systems, which are based on PMU's can not be neglected. Therefore a comparative analyses needs to prove that the new WAM systems can support additional features that the traditional off-line WAM systems and EMS/SCADA systems are not capable of. Because the post mortem system analyses can be sufficiently supplied with the data from the off-line WAM systems, it is expected that the on-line PMU based WAM systems will bring some added value into the operators control room or elsewhere.

While the existing EMS/SCADA systems can sufficiently enable the monitoring of Power System in normal operation, the control room operators are sometimes lacking of useful information, especially in case of near to danger or emergency system states. Many critical situations could be efficiently solved if the system operators would be able to follow the instability trend of the power system. However the instability phenomena are usually correlated with extensive changes of power system variables that the existing EMS systems are not able to observe. The system operators are therefore powerless of making any proper response during the escalation of emergency situation i.e. in the seconds or sometimes even minutes, whilst the switching of the critical lines or generators would still be possible. The WAM system can bring this critical information to the control room operator to focus his attention to the actual problem. Additional benefits of the on-line WAM systems can also be expected in the operational procedure of line recoupling. And the quality of some of the existing EMS tools can be improved. The later goes for on-line dynamic analysis, where the new WAM system can provide all data that is needed for the on-line sodel calibration e.g.

load model estimation. Because of very accurate and prompt measurements of the phase angles the on-line WAM systems can noticeable improve the quality of the state estimator.

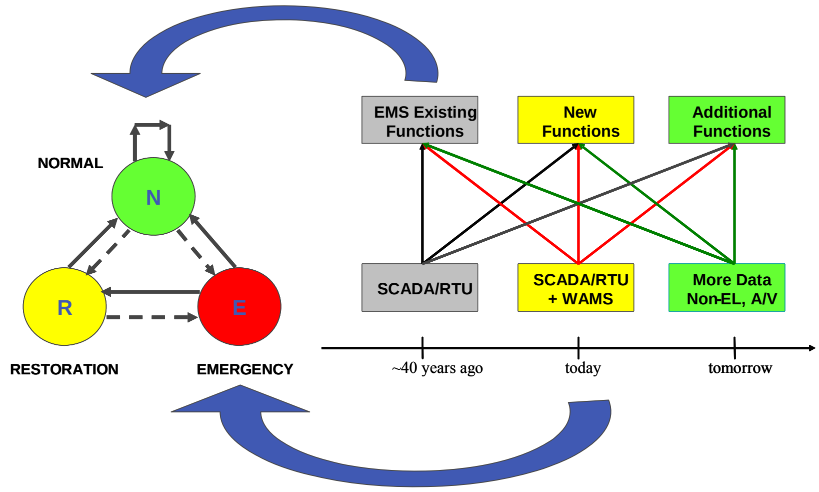

Figure 7: On-line WAM system in the operator control room [3]

And what can we expect from the on-line WAM systems in those system states where the system operator does not have enough time to respond? In this up-to-ten-seconds time frame the on-line WAM systems can be used to supply the data for Special or Rapid Protection Systems, which can protect the Power System to fail in a wider geographical scope that the existing Relay Protection devices can not cover.

CONCLUSIONS

The paper exposed the existence of dynamic stability margins for transit flows across Slovenian system which in addition to high amplitudes gained high volatility recently. Undisputable, fast and accurate information on electric power system performance are keys to reliable and secure system operation in the more and more stressed environment driven by market forces. WAM systems are expected to provide the "missing link" in EMS and bring the coordination between TSOs (not necessarily neighboring) to a higher level.

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