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Development of Capabilities of Phasor Measurement Devices and SMART-WAMS Complexes

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1 INTRODUCTION

WAMS technology (Wide Area Measurement System) is a new development direction of control systems in power system engineering. The main WAMS elements are special measuring devices – PMU (Phasor Measurement Unit), which can measure electrical network parameters with accurate time stamping. Implementation of this technology became possible due to wide extension of GPS and GLONASS satellite navigation systems. Satellite receivers can synchronize internal clocks of measuring devices with an accuracy up to 300 ns. High synchronization accuracy gives a possibility not only to measure parameters in different points of a distributed system (such as UPS) simultaneously, but also to measure current and voltage phase angles directly based on universal time. Information about current and voltage amplitudes and phases, measured simultaneously in different points of a network, results in a qualitatively new level of knowledge about power system properties and running processes.

Software and hardware complex named SMART-WAMS, designed by RTSoft in cooperation with SO UPS and Energy Systems Institute by request of a System Operator, forms a basis of Transient States Monitoring System, a Russian WAMS system. This publication summarizes a 6-year experience of SMART-WAMS operation and modernization and discusses possible directions of further development of this technology.

2 SMART-WAMS COMPLEX DEVELOPMENT

Software and hardware complex SMART-WAMS (see Figure 1) was developed in 2004 - 2005 according to System Operator's technical specification and C37.118-2005 international standard requirements [1]. RTSoft MIP-02 PMUs execute measuring function in SMART-WAMS, providing possibility of synchronization from GLONASS and GPS satellite receivers. Experiments on RTSoft test benches showed that phase angle values, hence synchronization accuracy, are virtually identical for GLONASS and GPS receivers within MIP-02 accuracy of observation (0.1 degree).

A series of comparative tests of MIP-02 and PMUs from leading world manufacturers using NIPT electrodynamic simulator was performed within the SMART-WAMS development period. The tests helped in significant improving of device parameters and in eliminating found imperfections.



Fig. 1: Exterior of SMART-WAMS complex

At the initial SMART-WAMS implementation stage one of the problems was lack of high speed communication channels at remote objects. Modem was the main device, communicating data to an upper level. So we paid a special attention to a possibility of autonomous complex operation and local data logging. An industrial computer with 2 Ethernet in SMART-WAMS ports provides data acquisition from PMU. One Ethernet port is used for data reception from PMU, another port is used to communicate with upper level of a data acquisition system. A 4 GB CompactFlash II flash drive is used to store operating system, applications and data archives. Archives are kept in 2 forms: cyclic and emergency. Full registration set includes more than 30 parameters. There is a separate set for each archive type, that is defined during system configuration. Due to the limited disk volume, increase in number of registered parameters leads to reduction of archive duration. In a standard configuration, full active and reactive power, amplitude, phase A frequency, phase A angle (bound to PPS (Pulse per Second) pulse from a satellite receiver) are recorded.

A trigger of a 20-minute emergency archive recording (typically 2 minutes prior to event and 18 minutes after event) is voltage deviation or network frequency rate of change. 50 emergency archives are recorded for each PMU. Appearance of a new emergency archive leads to deletion of the oldest record. Given 4 PMUs in SMART-WAMS complex and 4 GB flash drive,

duration of continuous cyclic archives constitutes 5 days. Archives are sent from server to an upper level via FTP protocol.

Practice showed low efficiency of emergency archives due to heterogeneous nature of oscillations in the network. With low trigger limits, time of emergency records storage was rather short. With high limits, PMU does not “feel” remote emergencies. In some cases storage duration of cyclic archives was insufficient. Measures for significant increase of archive duration were needed.

Replacing flash drive with another one with bigger capacity lead to significant computer deceleration, which negatively affected its reliability. A solution was found in simultaneous use of the flash drive and inexpensive large capacity HDD. The complex with new hardware retained its functionality, providing highly reliable storage of cyclic and emergency archives on CompactFlash II card. At that, cyclic archive with duration up to several months (depending on PMU number and registered parameters number) is replicated to the hard disk. Such a technical solution resulted in a significant improvement of complex performance and reliability.

Another direction of SMART-WAMS development was communication functionality of PMU and data acquisition server. Main technical solutions during SMART-WAMS designing were taken before acceptance of C37.118 standard. Data from PMU to the data acquisition server were transmitted using IEC 61870-5-104 protocol. Building Stability Margin Monitoring System (SMMS) in several districts of Tyumen power system required realization of C37.118 protocol in PMU. This system was not supposed support local data archiving. Data were sent to data acquisition center for storage via high speed communication channels. After embedded software update, MIP-02 PMU can simultaneously transmit data to a local server using IEC 61870-5-104 protocol and in two directions using C37.118 protocol. This allows PMU to acquire data locally for archiving and to transmit data on-line to real time applications in parallel.

To integrate existing SMART-WAMS complexes into SMMS, data acquisition server software was extended with retransmission feature using C37.118 protocol from one of connected PMUs. Without any hardware alteration, when high speed data channel becomes available, a possibility of real-time data transmission to data acquisition center appears. Currently, an extra small delay due to data processing on the server side is considered to be negligible, given the lack of necessity in hard real time.

3 FURTHER DEVELOPMENT OF SMART-WAMS COMPLEX

Main obstacles restricting wide application of WAMS technology are, by our opinion, high cost and lack of power object owners’ interest to implement this technology. Currently, System Operator is the only WAMS information consumer. Data are used for verification of electrodynamic model of power system, for low frequency oscillations analysis and other tasks, not related to interests of power object owners. At the same time, phasor measurement data can be used to solve a wide range of new tasks. Information about current and voltage amplitudes and angles with exact absolute time stamping can be used, for example, in real-time estimation of power line and equipment parameters, new relay protection algorithm realization, and in other fields, which wait for their developers.

SMART-WAMS complex can form a basis for new direction development, connected with phasor measurement technology. The server software structure provides for easy application set extension. Today, data acquisition server provides data flow retransmission using C37.118 protocol in addition to archive recording. Realization of retransmission technology using IEC 870-5-104 protocol is included in the immediate plans, that will permit using SMART-WAMS as a data source in telemetry and object control systems. It is planned to extend server’s communication capacity with data exchange using C37.118 and IEC 870-5-104 protocols, and to realize PDC (Phasor Data Concentrator) functionality according to new version of C37.118 standard, expected in 2011.

Direct measurement results transmission from MIP-02 PMUs using C37.118 protocol and bypassing data acquisition server is also possible, in order to implement algorithms with restrictions on measurement and data delivery time (see Figure 2).

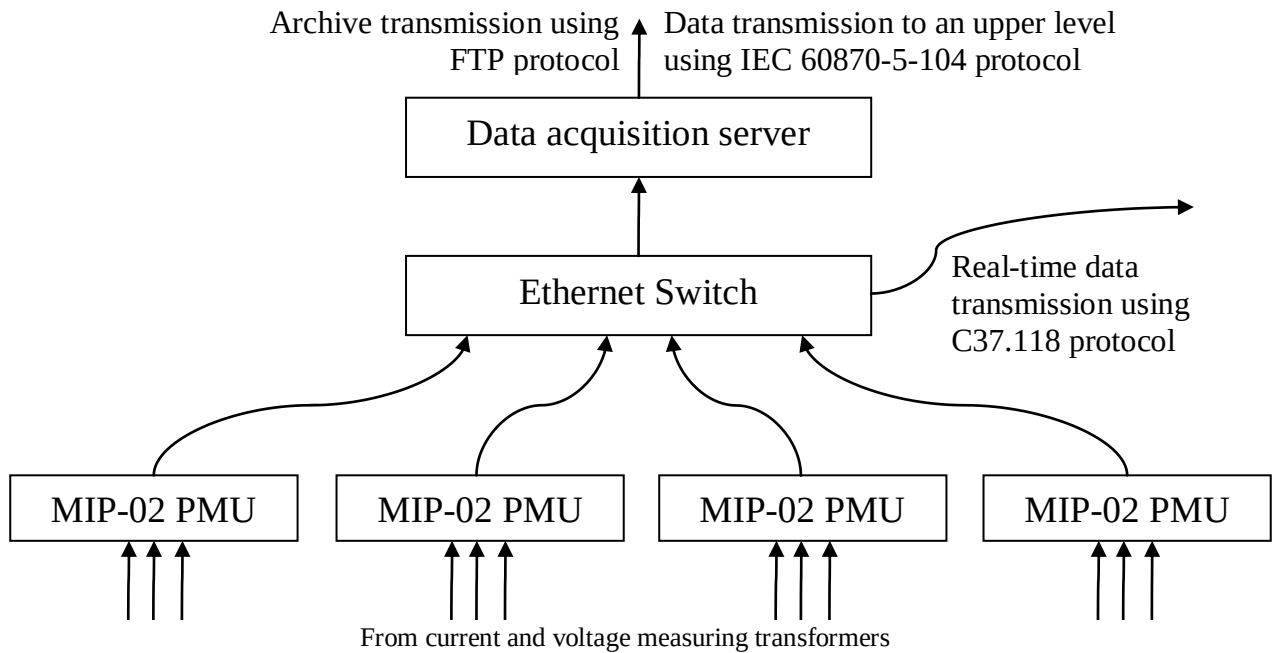


Fig. 2: Data flow structure in SMART-WAMS complex

Part of algorithms for new tasks, related to phasor measurements, can be implemented directly in the data acquisition server. In this case, SMART-WAMS complex becomes an instrument, which can be used as a replacement for new equipment, without any hardware modifications, including objects where the complex is already installed.

Another direction of further adoption of WAMS technology is development of new phasor measurement unit models. Development goes in the following directions:

- cost reduction;
- functionality extension;
- measuring accuracy improvement.

A new PMU model by RTSoft company has 2 separate inputs (see Figure 3) to control 2 separate three phase connections. This solution significantly reduces dimensions and cost of equipment. New MIP-02 modifications feature EMI protection according to IEC 61000-6-5:2001 and are certified for use at Federal Grid Company UES objects. These devices can be integrated into existing enterprise network along with other equipment. Phasor meters can also be used as data sources in telemetry and object control systems in addition to their basic functionality.



Fig. 3: New MIP-02 PMU with 2 inputs

New PMU model provides increased number of data transmission directions and significantly extended set of calculated parameters.

SMART-WAMS development experience made it possible to significantly improve accuracy of measuring of one of the main PMU parameters – voltage phase angle – bound to PPS pulse. Angle measurement accuracy of new MIP-02 model equals to 0.025 degree. It should be noted, that it is one of the “stable” parameters in real measurements, which has low sensitivity to interferences. At the same time, exact determination of its value tightly depends on calibration method and can significantly vary for different manufacturers. So measuring phase angle difference at the ends of power line segment, for example, devices from the same manufacturer should be used.

Measurement parameters	Accuracy
Voltage	$\pm 0,15 \%$
Current	$\pm 0,2 \%$
Frequency	$\pm 0,001 \text{ Hz}$
Voltage phase angle relative to PPS (measuring interval – 20 ms)	$\pm 0,025^\circ$
Voltage phase angle relative to PPS (measuring interval – 100 ms)	$\pm 0,01^\circ$

Table 1: Metrological specifications of MIP-02-40.01 PMU

4 CONCLUSION

Information content supplied by PMU measuring devices significantly exceeds that of telemetry devices. Taking into account that measurement synchronization accuracy in PMU has qualitatively different level, WAMS technology should replace classical telemetry in the future.

Further PMU development directions should be connected with development of universal measuring devices, which are intended for parallel execution of several tasks. Electrical network parameters monitoring is only one of these directions. Other distributed phasor measurement application areas, such as distributed relay protection, monitoring of primary electrical equipment parameters and so on, still wait for further development. Perhaps, it will require extra specific requirements (for example, measurement interval reduction).

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