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The registrator of parameters of the transient states «SMART-WAMS» and its testing

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SUMMARY

This paper defines technical requirements for registrator (phasor measurement unit, PMU) of IPS/UPS Wide area measuring system[1] that allow to quantify, compute, and archive phasor quantities of both emergency and pre-fault conditions. The PMU consists of a multifunctional measuring transducer and a communication server installed at the substations to provide for frequency, voltage, voltage phase-angle and power flow capacity measuring in any number of substation connections to the EPS.
The paper outlines the principles of measuring and computing basic operating parameters: active and reactive power, frequency, voltage phase-angles in the power system nodes , which are recorded and transmitted to the higher control levels. The operating parameter measurement accuracy indexes are specified. The most important of them are: frequency – 0.001 Hz, voltage phase-angle – one degree and power – 0,5%.
The results of tests of PMU SMART-WAMS on functioning and satisfaction to technical requirements performed on the digital-analogous-physical complex (EDS) of "NIIPT" are presented.

KEYWORDS

Registrator, Phasor measurement unit, Transients, Synchronized measurement, Operating parameters.

1. PHASOR MEASUREMENT UNIT

The phasor measurement unit (PMU) is the key element of WAMS. The unit consists of one or several multifunctional measuring transducers (MMT), of communication server and exact time signal equipment on the basis of GPS receiver. The architecture of communication server (CS) is shown on figure 1.

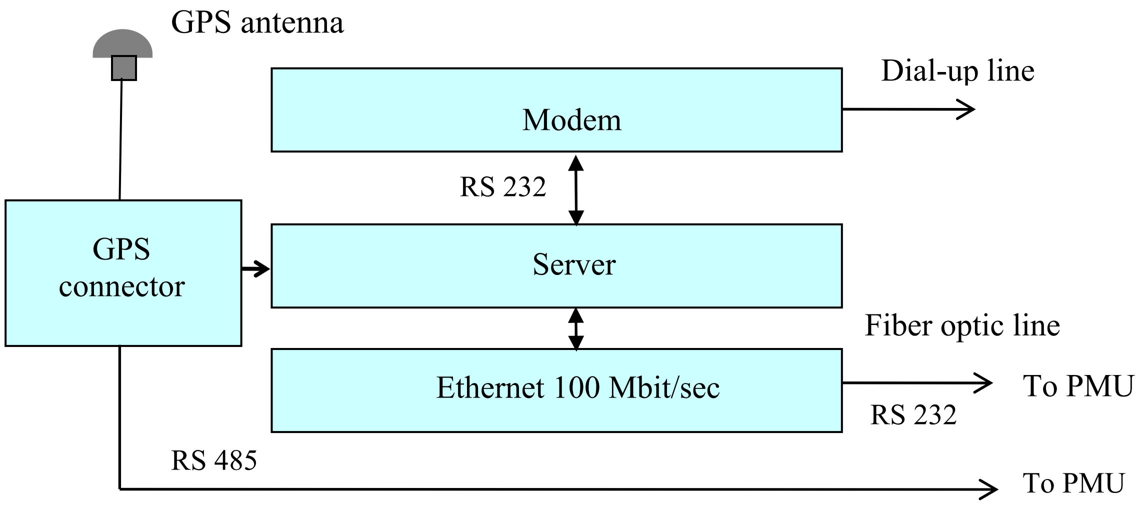

Fig. 1. Communication server architecture

The PMU's are devices meant for currents and voltages instantaneous value signals receiving, for measuring, computing, recording and subsequent transmitting the recorded information to the control centre. The unit records:

- frequency (for each phase, with reliability information);
- angle between grid voltage sine wave and 50 Hz sine wave, referenced to exact time signals;
- active power in each phase and total power of three phases;
- reactive power in each phase and total power of three phases;
- total power in each phase and total power of three phases;
- phase voltages;
- time.

PMU is installed in power plant or substation, the information is recorded and transmitted off-line in the form of archives to users via switched phone lines. The possibility of separate channel on-line data transmission is provided, too.

Multifunctional measuring transducer (MMT) architecture is shown on the figure 3.

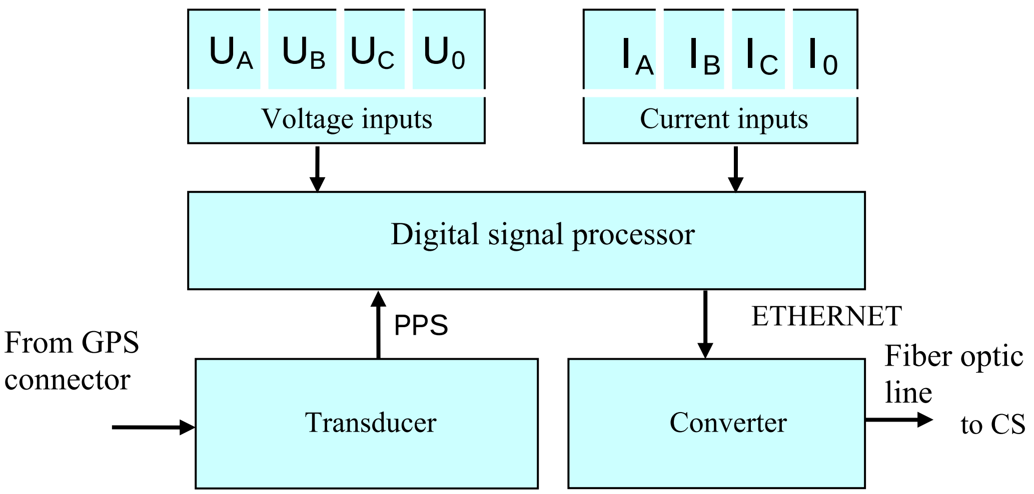

Fig. 3. Multifunctional measuring transducer architecture

Phase and neutral voltages from voltage transformers as well as phase and neutral currents from the test coils of current transformers are applied to MMT input. Signal levels are conditioned in the incoming circuits of the channels with input range of analog-to-digital converters (ADC) using resistance divider (for voltage signals) and current transformers (for current signals). ADC digital codes via optical isolation enter digital signal processor (DSP).

There are circular buffers of instantaneous signal values in DSP random-access memory. At one signal cycle 128 samples of instantaneous signal values are taken. Thus, if grid nominal frequency is 50 Hz, sampling frequency amounts to 6400 Hz.

In order to compute currents, voltages and powers at each master frequency, fast Fourier transform of 128-point ADC codes array is done as well as fundamental harmonic parameters are computed.

In order to compute frequency the appropriate voltage signal is digitized with frequency of 12800 Hz, is filtered by digital low frequency filter and then voltage zero-crossing points are defined using zero area linear approximation and signal cycle and frequency in Hz is computed. Such an approach ensures frequency determination accuracy of 0.001 Hz and power determination accuracy of 0.5%.

On the basis of current and voltage codes arrays the following parameters are computed:

1. Frequency is defined as value inverse to the time interval between the two nearest one direction zero-crossings of the signal.
2. RMS phase voltage and current are defined as rms values of main components, voltage and current signals.
3. Voltage between X and Y phases is calculated using the following equation

$$U_{XY} = \sqrt{U_X^2 + U_Y^2 - 2U_X U_Y \cos\delta},$$

where: U_X, U_Y are A, B, C phase voltages, and δ is phase shift between them.

4. Active and reactive phase power are calculated by the following equations

$$P_X = U_X I_X \cos\varphi, \; Q_X = U_X I_X \sin\varphi,$$

where: U_X is voltage, I_X is current, $\varphi=\varphi_U-\varphi_I$ is phase shift between voltage and current main component.

5. Active grid power and reactive grid power are calculated as sums of A, B and C phase active and reactive power.

6. Voltage phase-angle is calculated by the following equation

$$\psi_X = (t_Z - t_{PPS}) \cdot 50c^{-1} \cdot 360°,$$

where: t_Z is a positive direction voltage zero-crossing point,

t_{PPS} is zero-crossing point of the sine wave defined by second pulse. Angle calculation accuracy amounts to 1°.

PMU TESTING

For checking of the SMART-WAMS PMU on functioning and satisfaction to technical requirements, their tests have been performed on the digital-analogous-physical complex (EDS) of the JSC "NIIPT" [2] in the conditions approximated to the conditions of the future operation as much as possible. For this purpose in the structure of the EDS, the test scheme shown on the figure 1 has been created. The scheme represents a physical simulator of an electric power system including a thermal power station, hydroelectric power station, nuclear power station as well as a concentrated electric power system. As a concentrated electric power system, the large capacity synchronous machine or the Lenenergo buses can be used. The capacitive load and an element of power electronics (inverter) can be connected to the buses of a thermal power station.

For the reproduction of various scheme-regime and emergency conditions of an electric power system, the scheme is equipped with automatics allowing modeling various perturbations (technological emergencies).

The testing schedule included the experiments allowing executing an estimation of the correctness of digital recorders' functioning during:

- emergency outages of transmission lines;
- occurrence of open-phase modes;

- occurrence of emergency power unbalances;
- possible distortions of the form of a curve of the voltage, caused by various power electronics devices' operation.
- transitive modes caused by a start-up of asynchronous motors or switching of shunting reactors.

Emergency power unbalances were considered both at fast restoration of frequency in a power system (during parallel operation of the EDS with the electric power system of Lenenergo), and at a significant variation of frequency owing to the absence of the primary and secondary frequency control (during the isolated operation of the EDS and the turned-off governors).

The registration of the tests was carried out by means of the digital oscillography system. For the estimation of correctness of digital recorders' functioning, the high-speed analog data transdusers of voltage, angle, active and reactive power which are a part of the EDS instrumentation system were used. Before tests, the transducers have passed the preliminary calibration. Also, the digital frequency recorders developed in "NIIPT" were used for the tests.

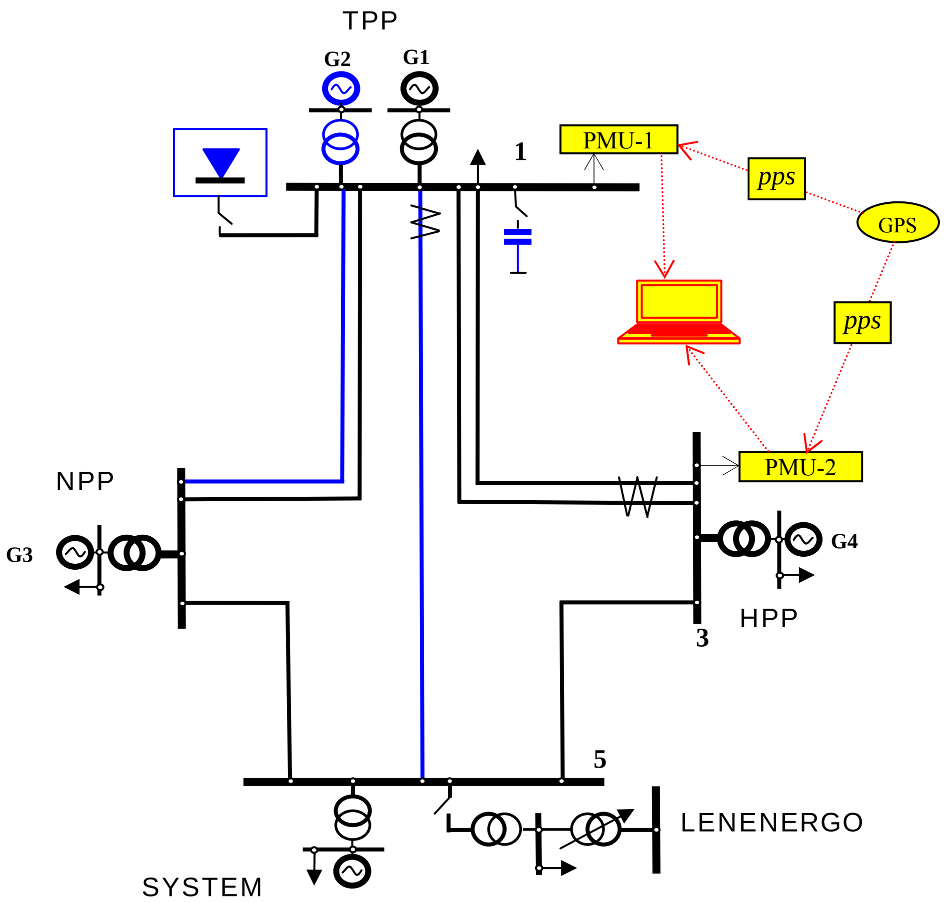

Fig 1. The test scheme of the power system constructed on the EDS.

Two pre-production models of the SMART-WAMS PMU have been connected to the high-voltage buses of a TPP (unit 1) and a HPP (unit 3). The synchronization of PMU was carried out through the GPS receiver (fig. 1).

During the tests, which had three stages, the inaccuracies in algorithmic and software parts were found out and eliminated.

On the figures 2-5 the oscillograms illustrating the variation of the recorded parameters at the occurrence of the most typical transients are given. From the figures one can see that readings of the SMART-WAMS PMU are in coincidence with the indications of the EDS high-speed data transdusers.

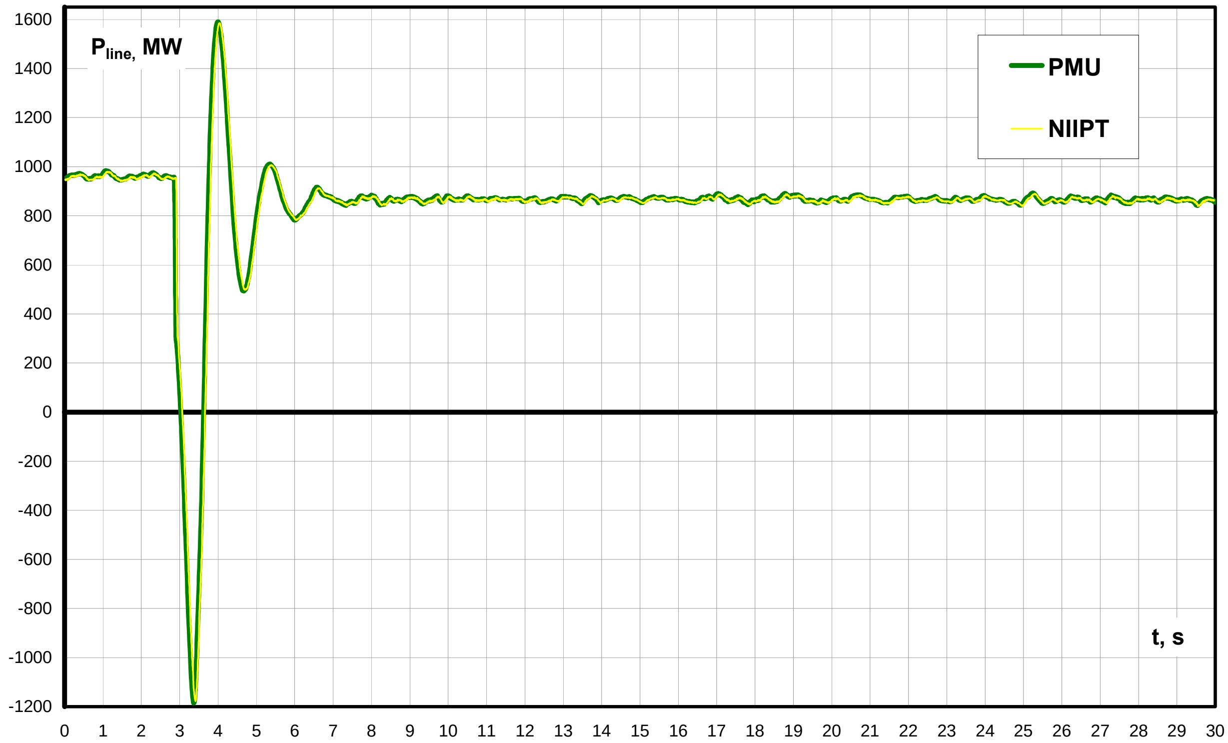

Fig. 2. Active power flow on 1-5 transmission line variation at start-up of a large asynchronous motor on the TPP buses.

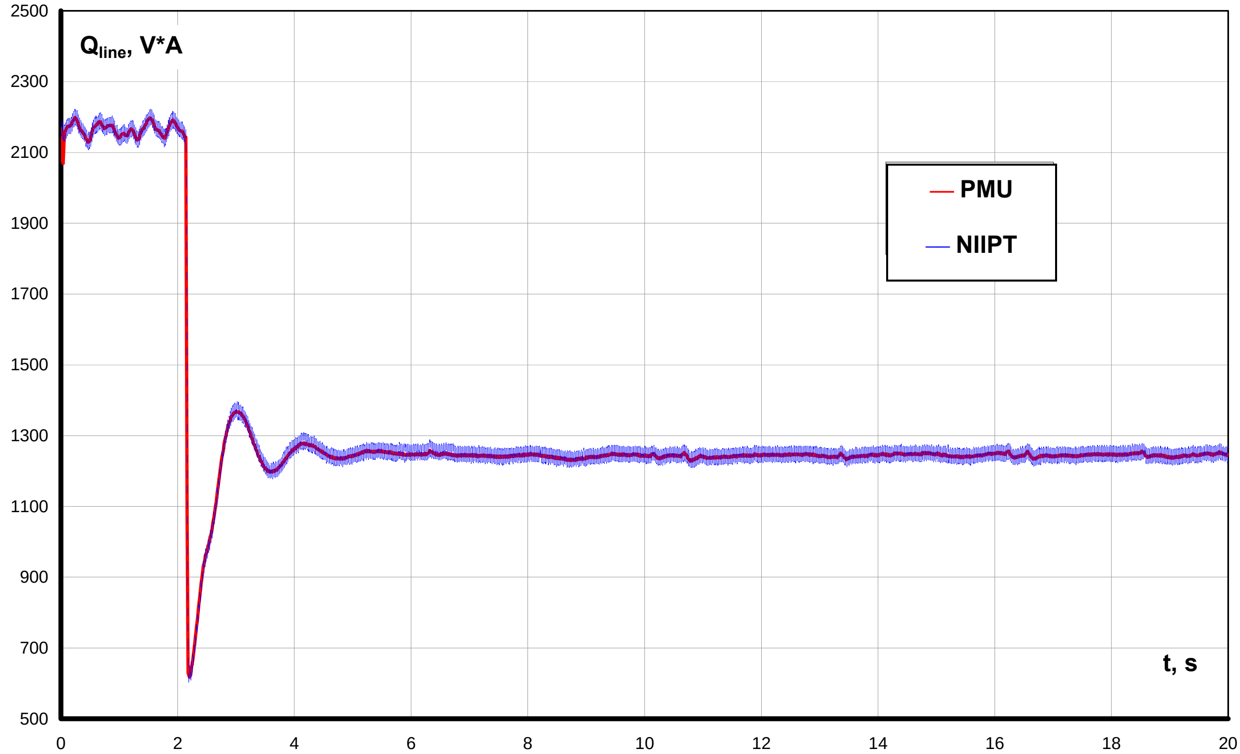

Fig.3. Reactive power variation at the outage of the generator G2 of the TPP.

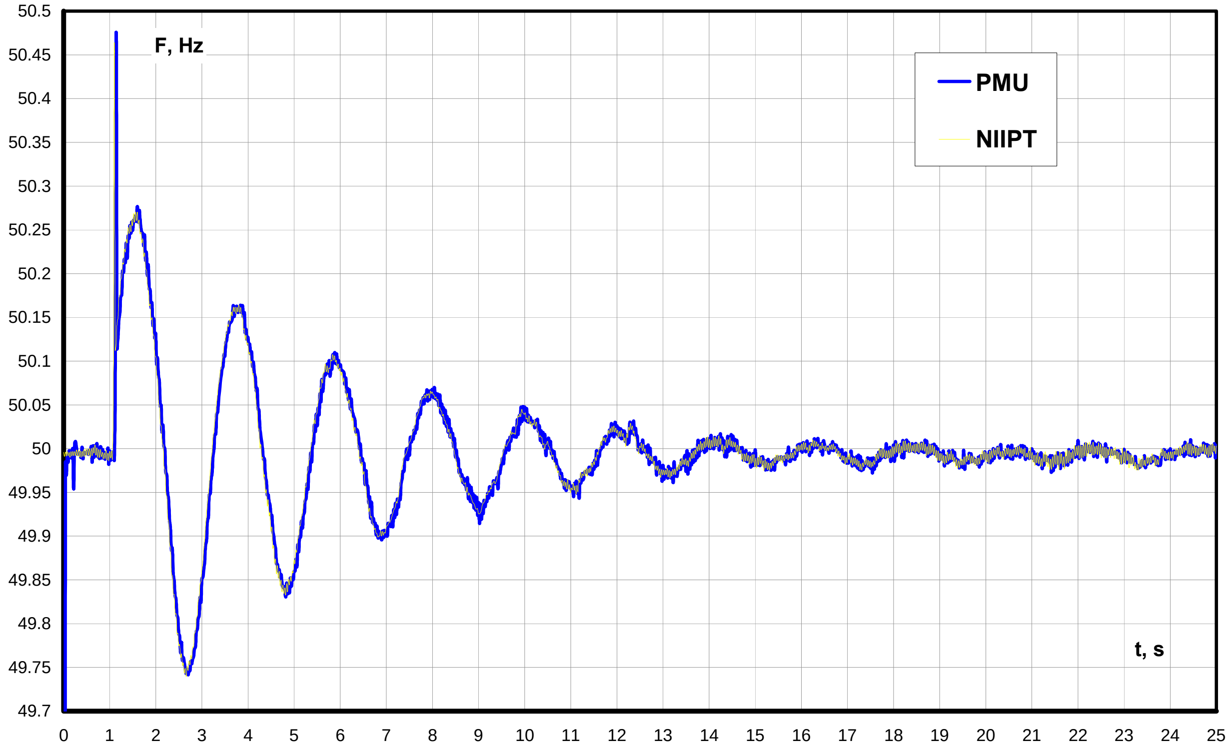

Fig. 4. Frequency variation at the outage of 1-5 transmission line.

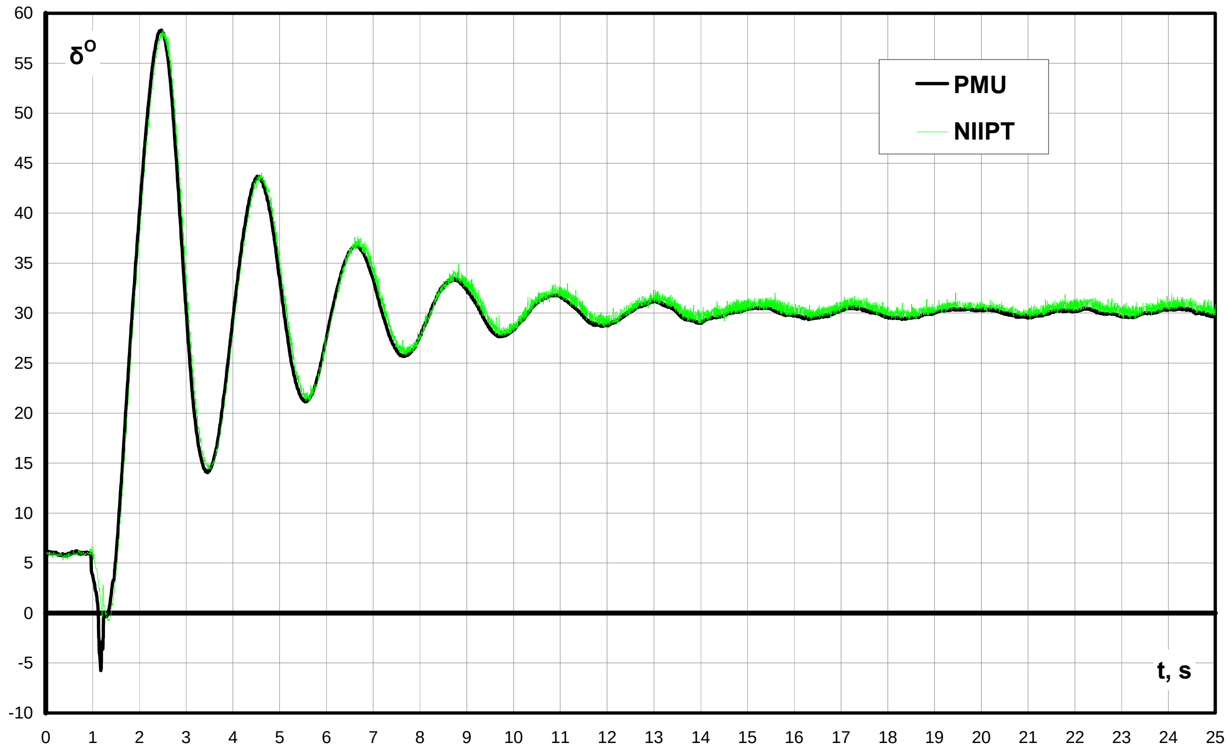

Fig.5 Relative angle variation between TPP and HPP buses at 2-phase SC on 1-5 transmission line with its outage.

The analysis has shown that the measurements of the transmission lines' active and reactive power, frequency in the point of connection and the angle relative to the absolute axis are made by PMU practically without a delay at all possible emergency perturbations with the accuracy defined by technical requirements.

Thus, the error in the definition of the relative corner between two vectors of the voltage measured in various points of the electric power system does not surpass 1°.

Thus, at all examined scheme-regime and emergency conditions the SMART-WAMS digital recorders work correctly and are functionally ready for commissioning.

References.

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