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Remote calibration of precision working standards of electric power

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Abstract **– Results of the research possibility of realization the system of remote calibration of precision working standards of electric power are presented. The analysis and research of the previously applied principles and methods for the realization of remote calibration of precision working standards of electric power were done. General operation algorithm, structural and functional scheme were developed also. Measurement model and the analysis of components of expended measurement uncertainty were described for first time.**

Keywords **– remote calibration, uncertainty, electric power, working standard.**

I. INTRODUCTION

For about 1500 working standards of electric power (WSEP) are operated in Ukraine.Which must be calibrated in accordance with the requirements of the new law of Ukraine «On metrology and metrological activity» and the national standard DSTU ISO/IEC 17025 [1].

National Standard of the electric power and power factor units and two Secondary Standards of the electric power unit are stored and operated in the SE «Ukrmetrteststandard» (Kyiv). Development of remote calibration system of precision working standards of electric power in the present transitional circumstances is relevant and economically justified because Ukraine has no territorial accredited calibration laboratory except SE «Ukrmetrteststandard».

That's why there are number of difficulties to calibrate WSEP: at first is delivery of WSEP to the calibration laboratory; secondly is dismantling/ assembling WSEP from operation places. Taking into account presented above difficulties, the question of development of a new trend in automation metrology research such as remote calibration (RC) of WSEP by means of the Internet becomes relevant.

The given approach allows operational control of metrological characteristics of WSEP. Also it will greatly reduce the time of calibration (meteorological research) of WSEP, reduce the cost of calibration (meteorological research) of WSEP, and the problems associated with the transport and transport costs will be kept to the minimum because all WSEP are in the customer's laboratory. To ensure the traceability of measurements is used mobile working standard of SE «Ukrmetrteststandard».

II. RELATED RESULTS IN THE LITERATURE

Modern information technologies are widely introduced in metrological practice during recent years. One element of this implementation is the calibration of measuring instruments (MI) using the Internet [2-6], which was named Internet Metrology (iMET). The National Institute of Standards and Technology (NIST) held the first RC of MI using a multifunctional mobile working standard in 2000 [7].

Organizational and technical systems for the implementation of such calibration of MI have been already legalized in some countries, particularly in Japan, USA, UK, Netherlands, Italy and others. Features of regulatory support of organizational and technical systems of RC of MI are considered in [8]. The systems of RC of MI of the electrical units were created and tested in SE «Ukrmetrteststandard» [9-11]. Fulfillment of requirements according to the international standard ISO/IEC 17025 for RC of MI when transporting standard equipment in the customer laboratories and operate the RC is reviewed in [12].

III. DESCRIPTION OF THE METHOD

The main property of calibration of WSPE is traceability of measurement results to National Standard of the units of the electric power and power factor through Secondary Standard of unit of electric power. As a multifunctional mobile working standard was chosen reference set of equipment: the reference electric power comparator COM 3003 ZERA GmbH, high precision generator of voltage and current MT 3000 ZERA GmbH, highly stable current amplifier MT 3000 Buster ZERA GmbH up to 120 A. This reference set of equipment is part of the Secondary Standard of unit of electrical power for industrial frequencies. For realization of RC of WSEP has been developed special software which satisfies all the requirements in international standard ISO/IEC 17025 for RC [12].

Specialized software consists of two parts: server software (Fig. 1); client software (Fig. 2).

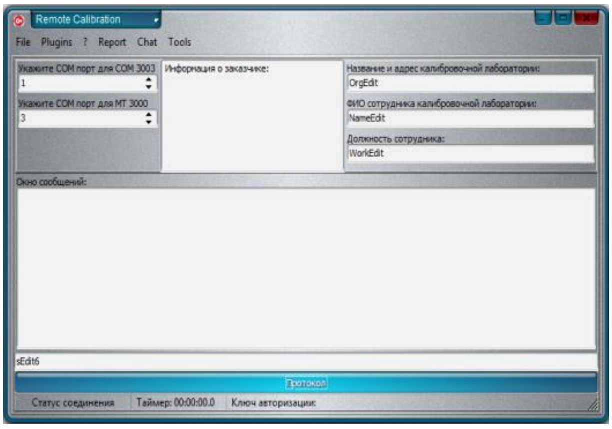

Fig. 1. The software window «Remote Calibration Server»

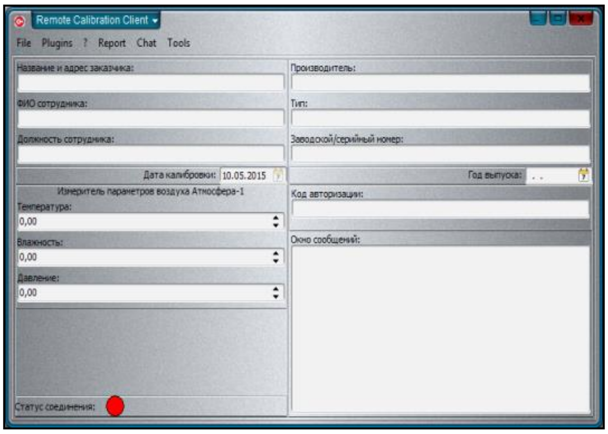

Fig. 2. The software window «Remote Calibration Client»

Specialized software and software SSM3000 are installed on a PC or device having access to the Internet in the calibration lab. Client software must be installed on a PC or device with Internet access to the COM port on the customer side.

Activation of client software occurs only in the presence of communication with the server software. The access to which have only authorized employees of calibration laboratory. Both components of the complex are password protected. Exchange between the server software and client software is done by mail protocols POP3-SNTP/IMAP. Such choice of protocols is determined by their prevalence in the Internet. That as a consequence allows using servers of protocols to transfer information without the need to create own dedicated server of information. The advantages of this specialized software are: the provision of open APE (Application Program Interface) interface control program, which lets to create own software modules to extend the functionality of the complex software; possibility of changing the appearance (interface); possibility of language selection of interface.

All information which is transmitted in the Internet is encrypted by the encryption algorithm RC6. At the end of RC the server program generates a calibration protocol and certificate.

Were detected attacks only against simplified versions of the algorithm, that algorithm with reduced number of rounds.

The encrypted information is transmitted to the Internet device management program, and the resulting information is decrypt data.

Appearance of the developed system of remote calibration of precision working standards of electric power is shown on Fig. 3.

The operation algorithm of remote calibration system of precision working standards of electric power is illustrated on Fig. 4.

Fig. 3. Appearance of the developed system of remote calibration of precision working standards of electric power

Also certain requirements are put forward for WSEP that are calibrated: the remote management interface and pulse output; multifunctionality of measurement/playback; high accuracy of measurement/playback. For realization of the system of RC functional scheme was developed which is shown in Fig. 5.

Developed system of RC of WSEP is widely used for RC of precision WSEP in Ukraine and abroad. Also developed system passed practically tested in SE «Ukrmetrteststandard» and other enterprises and practically applied to real long routes over 8,000 km.

The measurement test was done at the measured points: voltage 120 V; current 5 A; power factor 0.5L; 1.0; 0.5C; frequency 50 Hz.

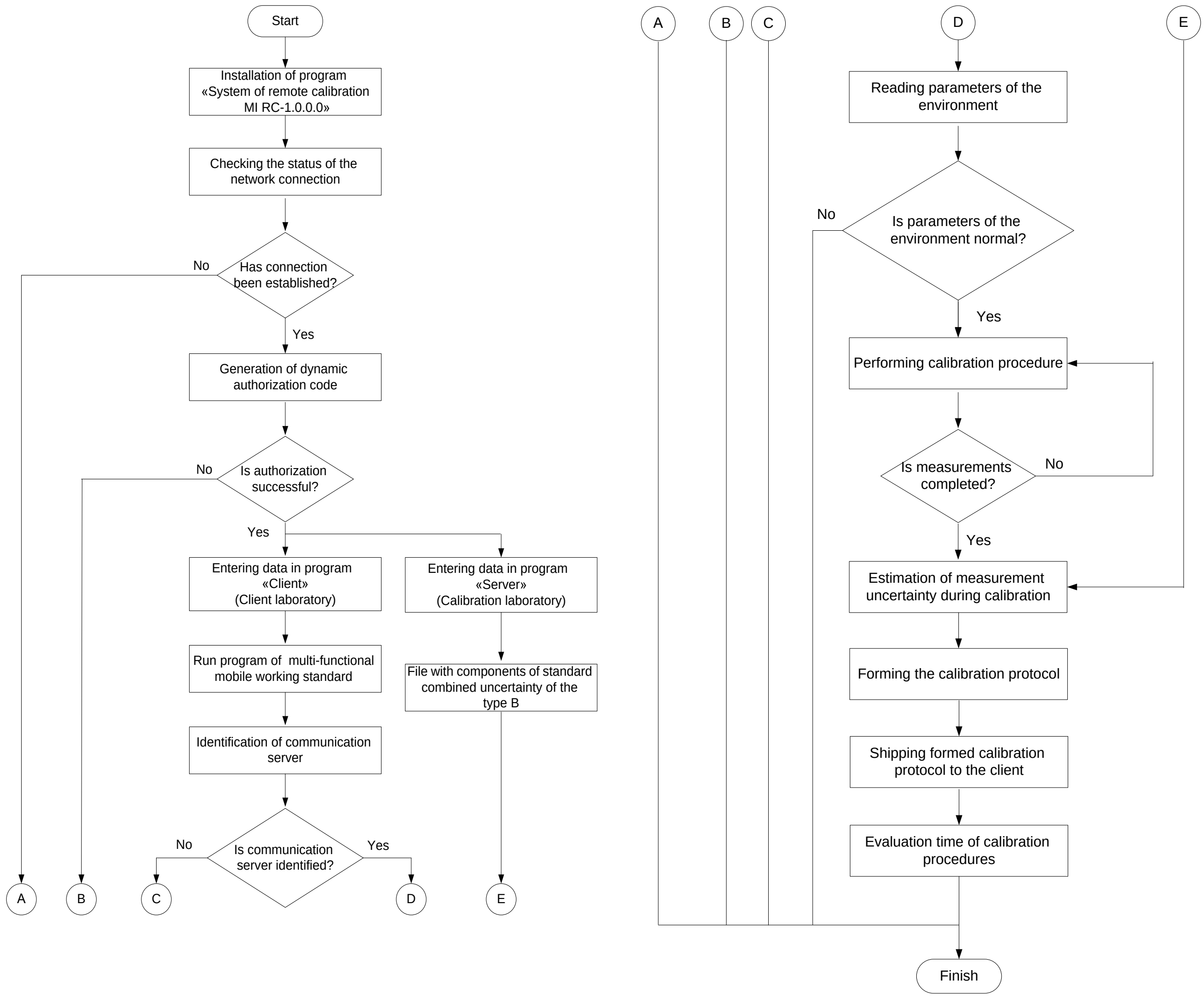

Fig. 4. The operation algorithm of remote calibration system of precision working standards of electric power

For calculation standard deviation of measurement results were done 20 measurements at one measurement point.

The measurement results (mean value, standard deviation and expended uncertainty) are shown in the Table 1.

Also were calculated the time for each session, overall time and average time of the measurements.

The results time measurements of the measurement test are shown in the Table 2.

The graph of dependence time of calibration from the distance between calibration and customer laboratories is shown on Fig.6.

IV. NOVELTIES IN THE PAPER

At first was written the measurement model for RC of WSEP in absolute form [13, 14]:

$$P_x = P_{0r} + \Delta_{\text{CKB}r} + \Delta_{\text{COM3003}} + \Delta_{\text{MT3000}} + C_{\text{MT3000Buster}} \cdot \Delta_{\text{MT3000Buster}} + C_{PF} \cdot \Delta_{PF} + \Delta_{TIME}, \qquad (1)$$

where: P_{0r} – the actual value of electric power (in absolute form); $\Delta_{\text{CKB}r}$ – the value of the standard deviation of the results of RC of WSEP; Δ_{COM3003} – the error of the reference electric power comparator COM 3003, during measuring the unit of electric power; Δ_{MT3000} – the error of high precision generator of voltage and current MT 3000, during playback the unit of electric power; $\Delta_{\text{MT3000Buster}}$ – the error of highly stable current amplifier MT 3000 Buster up to 120 A during playback the unit of electric power; $C_{\text{MT3000Buster}}$ – dependency coefficient of the measured electric power by instability of highly stable current amplifier MT 3000 Buster up to

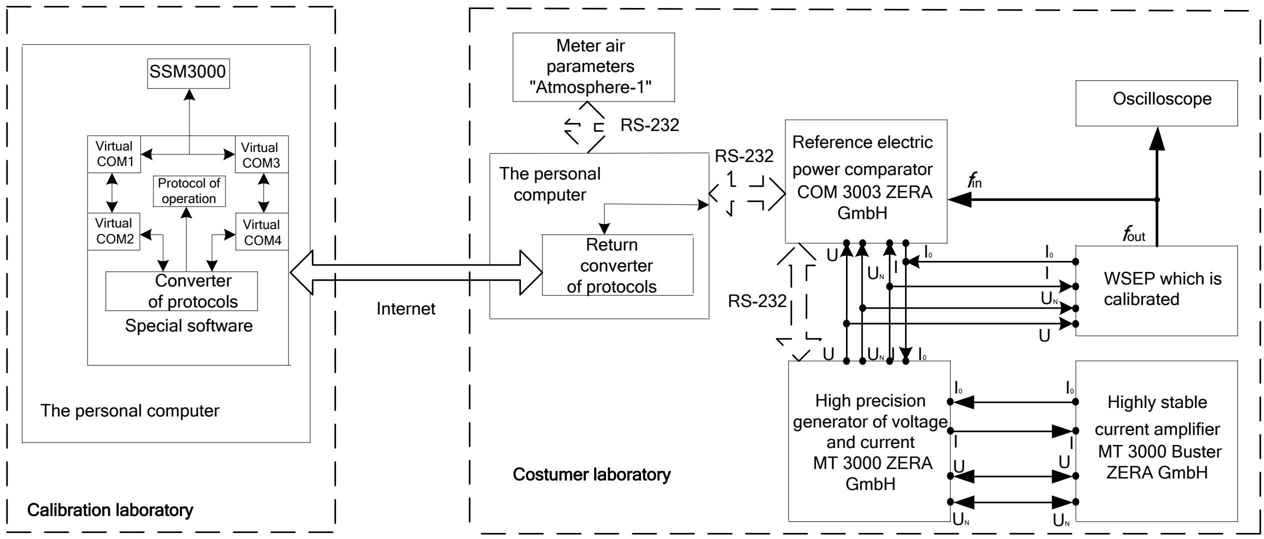

Fig. 5. Functional scheme of the developed system of remote calibration of precision working standards of electric power

Table 1. The results of the meaurement test for remote calibration of precision working standards of electric power

	Trace	Distance, km	Measured point (120 V, 5 A, 50 Hz)	Measured value, W/VA		
				Mean value	Standard deviation	Expended uncertainty
1	Kyiv (local)	0.05	0.5 L	-0.0260	0.00118	0.000729
			1.0	-0.0287	0.00130	0.000769
			0.5 C	-0.0276	0.00185	0.000968
2	Kyiv-Odesa (Ukraine)	450	0.5 L	-0.0310	0.00138	0.000796
			1.0	-0.0289	0.00138	0.000796
			0.5 C	-0.0254	0.00107	0.000694
3	Kyiv-Erlangen (Germany)	1400	0.5 L	-0.0290	0.00143	0.000814
			1.0	-0.0268	0.00147	0.000828
			0.5 C	-0.0235	0.00150	0.000839
4	Kyiv-Toronto (Canada)	7600	0.5 L	-0.0277	0.00162	0.000882
			1.0	-0.0250	0.00095	0.000659
			0.5 C	-0.0209	0.00143	0.000814
5	Kyiv-Manila (Philippines)	8800	0.5 L	-0.0266	0.00149	0.000835
			1.0	-0.0236	0.00149	0.000835
			0.5 C	-0.0194	0.00143	0.000814

120 A (dimension V); Δ_{PF} – the error that is caused by deviation of the phase angle between current and voltage of the set value, during measuring the unit of electric power; C_{PF} – dependency coefficient of the measured electric power on the deviation of phase angle between current and voltage of the set value (dimension W); Δ_{TIME} – the temporary instability of the reference electric power comparator COM 3003.

The measurement model for RC of WSEP in relative form looks:

$$\hat{P}_x = \hat{P}_{0r} + \delta_{\text{CKB}r} + \delta_{\text{COM3003}} + \delta_{\text{MT3000}} + \\ + \delta_{\text{MT3000Buster}} + \delta_{PF} + \delta_{TIME}, \quad (2)$$

where: $\hat{P}_{0r}$ – the actual value of electric power; $\delta_{\text{CKB}r}$ – the value of the standard deviation of the results of RC of WSEP (in relative form); δ_{COM3003} – the error of the reference electric power comparator COM 3003, during measuring the unit of electric power (in relative form); δ_{MT3000} – the error of high precision generator of voltage and current MT 3000, during playback the unit of electric power (in relative form); $\delta_{MT3000Buster}$ – the error of highly stable current amplifier MT 3000 Buster up to 120 A during playback the unit of electric power (in relative form); δ_{PF} – the error that is caused by deviation of the phase angle between current and voltage of the set value, during measuring the unit of electric power (in relative form); δ_{TIME} – the temporary instability of the reference electric power comparator COM 3003 (in relative form).

Table 2. The results of time measurements of the measurement test for remote calibration

	Trace	Distance, km	Measured point (120 V, 5 A, 50 Hz)	Measured time, hour:min:sec.				
				Session 1	Session 2	Session 3	Average	Total
1	Kyiv (local)	0.05	0.5 L	0:15:05	0:15:30	0:15:11	0:15:15	0:38:39
			1.0	0:08:33	0:08:26	0:08:17	0:08:25	
			0.5 C	0:14:59	0:14:56	0:15:00	0:14:58	
2	Kyiv-Odesa (Ukraine)	450	0.5 L	0:15:21	0:15:19	0:14:54	0:15:11	0:38:35
			1.0	0:08:18	0:08:24	0:08:20	0:08:21	
			0.5 C	0:15:04	0:15:03	0:15:01	0:15:03	
3	Kyiv-Erlangen (Germany)	1400	0.5 L	0:15:25	0:15:22	0:15:18	0:15:22	0:38:54
			1.0	0:08:44	0:08:23	0:08:28	0:08:32	
			0.5 C	0:14:42	0:15:02	0:15:17	0:15:00	
4	Kyiv-Toronto (Canada)	7600	0.5 L	0:15:25	0:15:27	0:16:19	0:15:44	0:39:00
			1.0	0:08:21	0:08:20	0:07:56	0:08:12	
			0.5 C	0:15:09	0:15:00	0:15:03	0:15:04	
5	Kyiv-Manila (Philippines)	8800	0.5 L	0:15:32	0:15:40	0:15:30	0:15:34	0:38:59
			1.0	0:08:20	0:08:20	0:08:17	0:08:19	
			0.5 C	0:15:09	0:15:09	0:14:59	0:15:06	

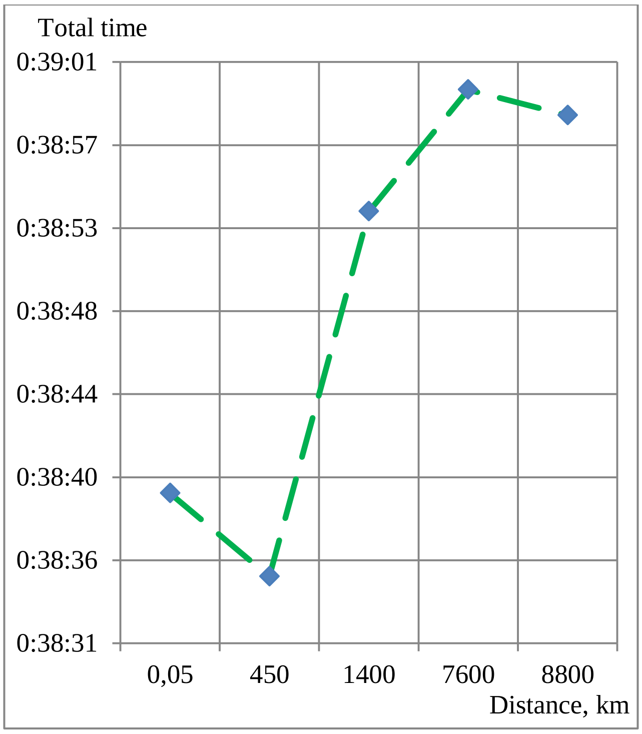

Fig. 6. The graph of dependence time of calibration from the distance between calibration and customer laboratories

The components of the budget total standard uncertainty will analyze. Expression for the standard combined uncertainty is given by:

$$u_C(P) = \sqrt{u_A^2(P) + \sum_{i=1}^{n} u_{Bi}^2(P)} = \sqrt{u_A^2(P) + 6{,}33\cdot 10^{-8}}. \quad (3)$$

The effective number of degrees of freedom according to EA-4/02 and JCGM 100 can be calculated as follows:

$$\nu_{eff} = \nu_{effA}[u_c(P)/u_A(P)]^4 . \quad (4)$$

The expanded uncertainty at 95% confidence level and the coverage factor $k = 2$ become:

$$U = t(P,\nu_{eff})\cdot u_c(P) = k\cdot u_c(P) = 2\cdot\sqrt{u_A^2(P) + 6{,}33\cdot 10^{-8}}, \quad (5)$$

where: $t(P,\nu_{eff})$ – coverage coefficient is equal to 2, with 95% confidence level.

By the results of the evaluation of the combined standard uncertainty of the measurement result electric power is composed uncertainty budget, which is given in Table 3.

V. CONCLUSIONS

The system of RC of WSEP was created and tested for the first time. It can reduce the time required to perform the calibration and to solve the problems of transportation WSEP from the customer of the calibration to the calibration laboratory. That is an advantage of this form of calibration. RC of WSEP was done in Ukraine and abroad. At first was written the measurement model for RC of WSEP. Also were evaluated the components of common standard uncertainty of measurements for RC of WSEP and composed uncertainty budget.

Table 3. The budget of components of expended uncertainty of measurements for remote calibration

	The input value x_i	The evaluation of the input value	The total standard uncertainty, $u(x_i)$	The law of distribution	The sensitivity coefficient, $\frac{\partial\Delta}{\partial x_i}$	The contribution of the relative uncertainty
1	δ_{CKBr}	δ_{CKBr}	$u_A(P)$	uniform	1.0	$u_A(P)$
2	$\delta_{COM3003}$	0.000026	0.0000130	normal	1.0	0.0000130
3	δ_{MT3000}	0.000030	0.0000150	normal	1.0	0.0000150
4	$\delta_{MT3000Buster}$	0.000030	0.0000150	normal	1.3	0.0000195
5	δ_{PF}	0.000500	0.0002500	normal	1.0	0.0002500
6	δ_{TIME}	0.000001	0.0000005	normal	1.0	0.0000005
7	$u_c(P)$					$u_c(P)$

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