Software Supported Procedure applied to Testing of Instruments for High-order Harmonics Measurement

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***Abstract*—Software supported procedure, applied for generation of the test voltage waveforms with certain level of the standard harmonic disturbances, is presented in this paper. Procedure is functionally based on the virtual instrumentation concept, which includes control application in LabVIEW software environment and data acquisition board NI PCIe 6343. Variation of the basic parameters for definition, presentation and signal generation is provided by various control functions and switches, implemented on front panel of the developed virtual instrument. For specific harmonic disturbances is possible to define percentage amounts of the harmonic amplitude levels, nominal frequency variations, amplitude fluctuations, start and stop times, rising and falling times of the disturbances. Described acquisition system is verified by testing of the three-phase power quality analyzer Fluke 435 Series II. By this generation system is possible to provide various voltage test waveforms with typical harmonic disturbances. In this specific case, for testing purpose are used some characteristic test waveforms with harmonic disturbances. Basic measurement results and some recorded voltage signals, obtained from testing procedure, are presented and analyzed in this paper.**

Keywords-Software supported test procedure; signal harmonic disturbances; virtual instrumentation software; voltage waveforms.

I. INTRODUCTION

Increased using of the power electronic components and powerful switching devices directly causes degradation of electrical power quality (PQ), which affects on the production process costs and reduces reliability of the customer electrical devices and equipment. In order to avoid these problems and to increase total energy efficiency level, electricity suppliers must provide appropriate quality of the power distribution networks. For purpose of the customer protection, satisfactory PQ level is prescribed by the relevant international quality standards and documents [1,2]. Optimal PQ level is defined with acceptable interval values of the standard quality parameters and some typical network disturbances. Relevant information, necessary for assessment of the power distribution network quality level, can be provided by measurement and detailed analysis of the basic quality parameters at some specific locations in the power distribution network. Different types of devices and equipment for measurement and software based processing of the standard PQ parameters are available at the market. These instruments are developed to perform continuous monitoring of the power supply quality level at specific locations in power distribution networks. By measurement of the relevant quality parameters, which includes performing of software supported statistical and diagnostic activities in single or three-phase power distribution networks, these instruments are capable to verify compliance of the measured parameters with relevant PQ standards [3,4].

In order to satisfy specified parameters and measurement accuracy level, these measurement devices must be followed by an appropriate metrological traceability chain. Metrological verification and testing of such instruments must be performed inside appropriate metrological laboratories. Reference devices, such as voltage and current calibrators, are available in various functional and constructive solutions. Such voltage and current calibrators are sources of the reference test signals with high accuracy levels, which correspond to the secondary standards, laboratory and industrial standards in metrological traceability assurance chain. Also, there are special calibration instruments for some specific types of the PQ meters, such as solutions of the multifunctional calibrators Fluke 5520A and Fluke 6100B, supported by some special PQ calibration functions [5].

Acquisition system described in this paper is developed in LabVIEW [6] software package for generation of the reference voltage test signals, including special functions for simulation of the high-order harmonic disturbances, typical for real power distribution networks. Signal generation process is functionally based on the virtual instrumentation concept, which includes control software application and acquisition board PCIe 6343. Software support provides definition and presentation of the reference voltage waveforms. Number of the control functions, implemented on control panel, provides adjustment of the basic parameters for definition, presentation and signal generation. Test waveforms, defined directly from control block diagram according to requirements of the European PQ standard EN 50160, can be used for generation of the various test sequences. For this specific purpose are generated voltage test waveforms with some typical combinations of signal high-order harmonic disturbances. Generated voltage test waveforms are applied for testing of the three-phase PQ analyzer Fluke 435 Series II [7].

II. LABVIEW SOFTWARE SUPPORT OF THE PROCEDURE

Data acquisition system for generation of the standard PQ parameters and high-order harmonic disturbances is developed. It can generate test waveform sequences including all types of the PQ disturbances defined by European standard EN 50160.

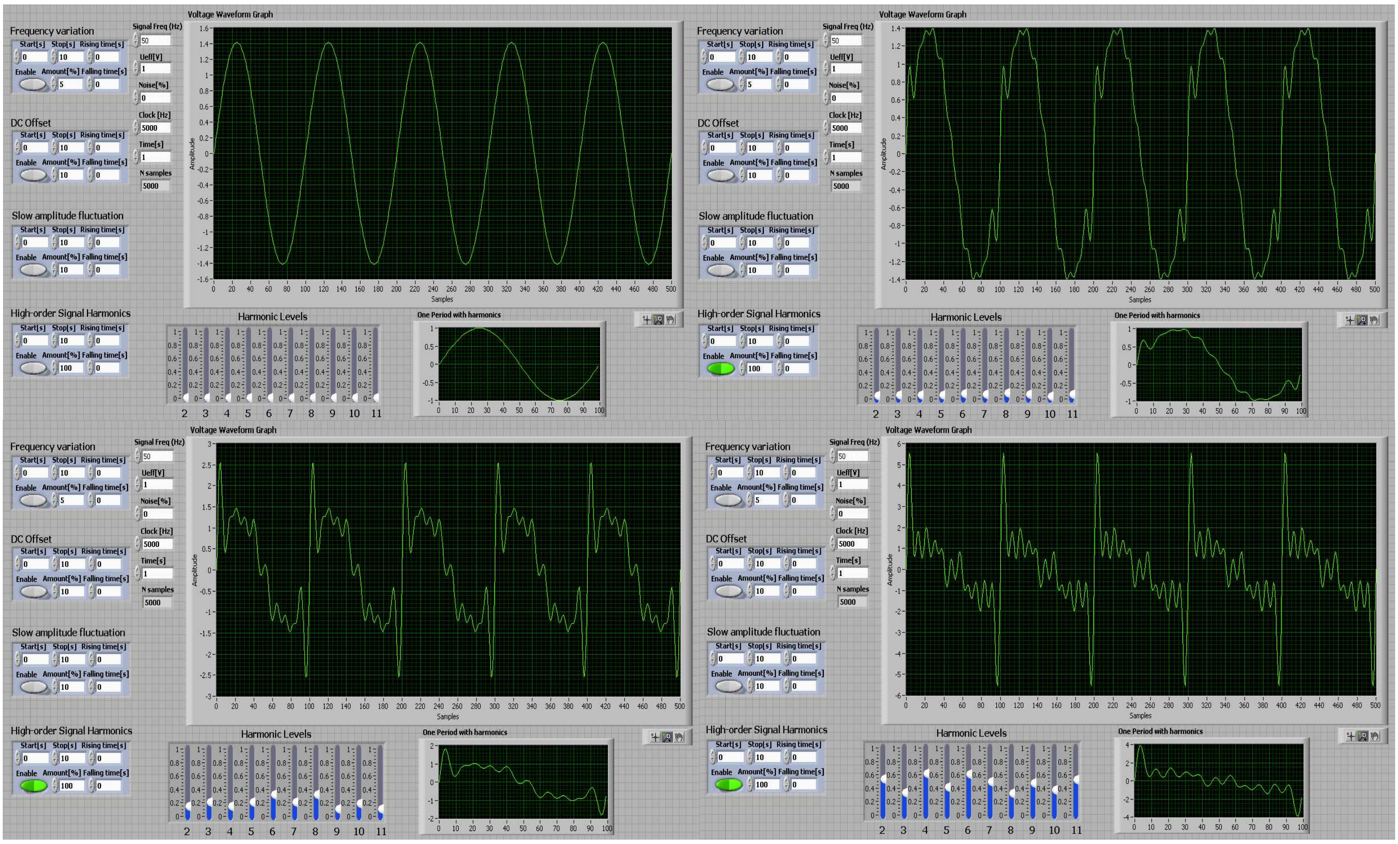


Figure 1. Control front panel in LabVIEW environment for generation of the voltage test waveforms (various levels of the high-order signal harmonics)

Main requirements were to enable combining a number of the various PQ disturbances in one complex signal test sequence, but also to include certain level of the noise, small voltage and frequency variations. Developed generation procedure includes standard computer with control programming application in LabVIEW software environment and data acquisition board NI 6343, equipped with standard block for connection SCB-68A. Entire procedure includes two connected functional part. First part of this procedure provides definition and simulation of the standard signal waveforms, with selected maximum levels of the specific high-order harmonic disturbances. Definition of the basic signal parameters for different types of the disturbances can be performed directly inside control front panel and block diagram of the LabVIEW virtual instrument [8]. Control front panel enables fast and simple correction of the basic waveform parameters, according to some specific user requirements and demands. Second functional part of this generation process is focused on real-time generation of the previously defined test voltage waveforms with standard harmonic disturbances, using analog outputs of the data acquisition board NI 6343. This is 32-channel PCIe acquisition card, with digital to analog signal conversion, output signal range of ±10V and 16-bit resolution.

Control front panel of the virtual instrument in LabVIEW software environment, developed for generation and graphical presentation of the voltage test waveforms, is shown in Fig. 1. This control front panel provides selection and variation of the basic signal parameters, by number of the control functions and knobs, implemented in block diagram of the virtual instrument. Some important functions are: definition of the nominal signal amplitude and frequency, definition of the signal sample rate and duration of the final test sequence, adding of the Gaussian noise in generated test signal, slow variation of the nominal signal frequency value, slow variation of the signal amplitude value with defined variation frequency and changing signal DC offset, voltage swell and voltage sag. Separated segment of the control functions on this front panel is used for selection and variation of the specific amplitude levels related to individual high-order harmonic components. Content of the specific high-order harmonics can be precisely determined by number of the control knobs for regulation of the harmonic amplitude levels. Shown test waveforms are generated with nominal frequency value of 50Hz and normalized RMS voltage value of 1V. Here are presented four different cases of the voltage test waveforms with various levels of the high-order signal harmonics. In order to be more realistic in generation of the signal waveforms, for particular harmonic disturbances is enabled separate definition of the nominal frequency variation, signal DC offset, amplitude fluctuations, start and stop times of the disturbances, rising and falling times and percentage amount of the harmonic amplitude levels from 2^{nd} to 11^{th} high-order signal harmonic components.

III. Presentation of Experimental Test Results

Previously described data acquisition system can be used as software based generator of the reference voltage waveforms, applicable in testing of various instruments for measurement and processing of the standard PQ parameters and high-order harmonic disturbances. As practical example, in this paper is described experimental procedure for testing of the three-phase

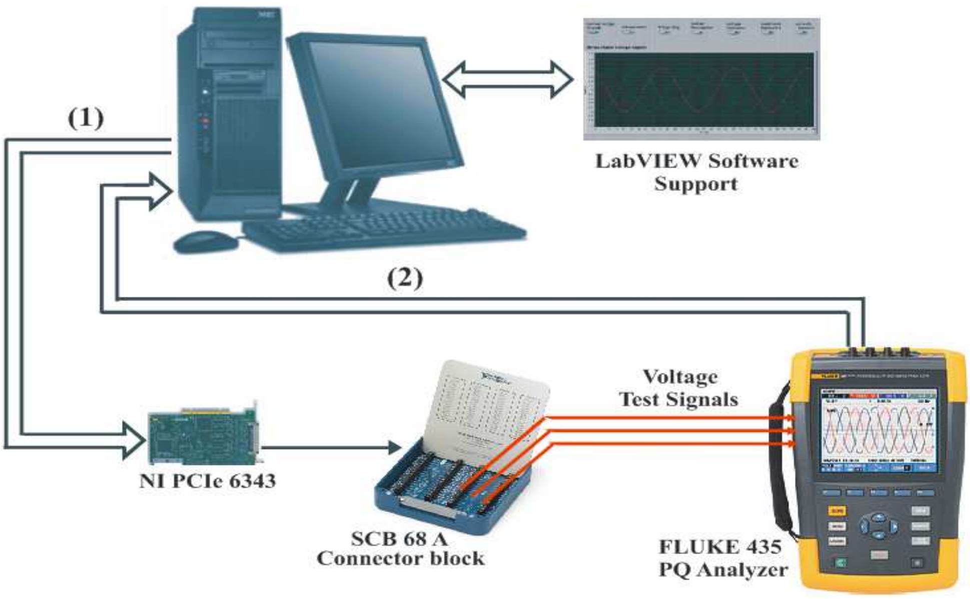


Figure 2. Basic hardware configuration of the software supported procedure applied to testing of three-phase PQ analyzer Fluke 435

PQ analyzer Fluke 435 Series II, in operational mode for high-order harmonics measurement. Basic hardware configuration of this test procedure is presented in Fig. 2. Reference voltage test signals, previously defined and generated with certain level of the harmonic disturbances, can be sent directly to the voltage inputs of the tested measurement instrument Fluke 435, using analog output channels of the data acquisition board NI PCIe 6343 and standard connector block SCB 68A (communication line 1). Instrument need to be set to work in operational mode for measurement of the high-order harmonics. Direct two-way communication between instrument outputs and computer is provided using standard USB interface (communication line 2). Obtained measurement results from instrument outputs can be simply transferred directly to computer, recorded into database and processed for graphical presentation. Some of experimental measurement data are shown in following section of this paper.

Software controlled test procedure includes three functional segments. First functional segment is recording of the voltage test waveforms on a graphical display of the tested instrument Fluke 435. Second part of this process includes measurement of the percentage values for individual high-order harmonic components in test waveforms. Third segment of the procedure is recording of the graphs for measured individual high-order signal harmonics, related to test signals. Four examples of the voltage test signals, recorded on graphical display of the tested analyzer Fluke 435, are shown in Fig. 3. These specific signals correspond to the test waveforms generated with various levels of the high-order disturbances, previously illustrated in Fig. 1.

Measurement results, related to percentage RMS values of the high-order harmonic components for test signals, obtained by measurement instrument Fluke 435, are presented in Fig. 4.

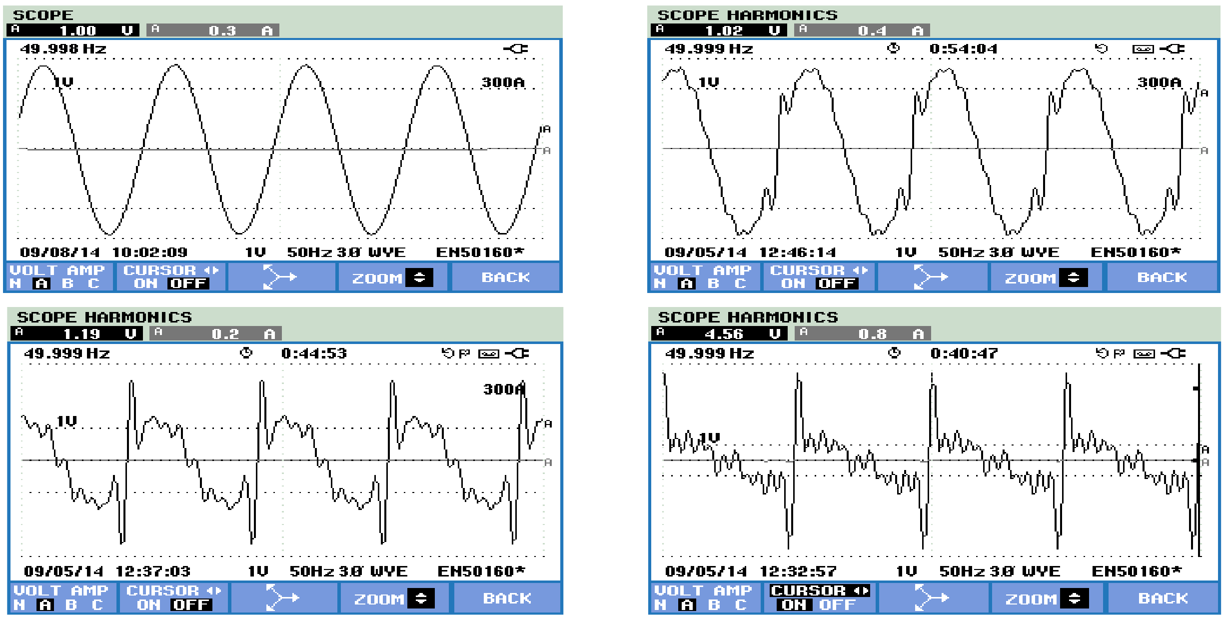
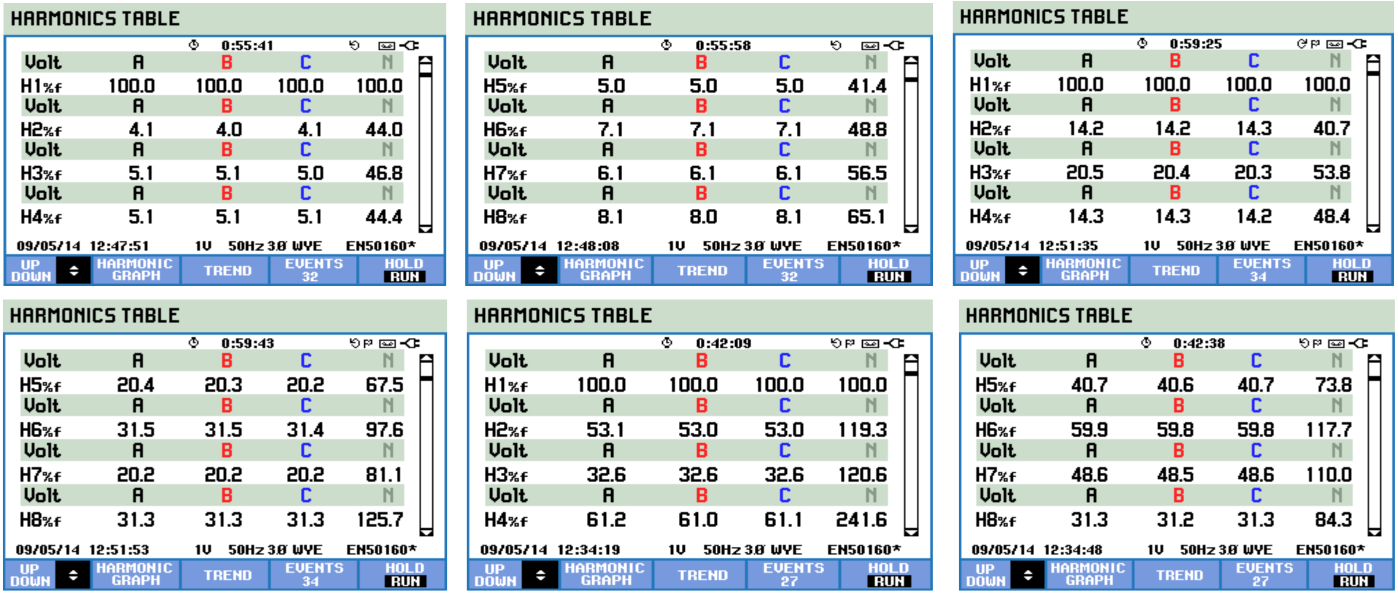


Figure 3. Test voltage waveforms recorded on graphical display of the measurement instrument - PQ analyzer Fluke 435



HARMONICS TABLE — 0:55:41 — 09/05/14 12:47:51 — 1V 50Hz 3Ø WYE EN50160*

Volt	A	B	C	N
H1%f	100.0	100.0	100.0	100.0
H2%f	4.1	4.0	4.1	44.0
H3%f	5.1	5.1	5.0	46.8
H4%f	5.1	5.1	5.1	44.4

HARMONICS TABLE — 0:55:58 — 09/05/14 12:48:08 — 1V 50Hz 3Ø WYE EN50160*

Volt	A	B	C	N
H5%f	5.0	5.0	5.0	41.4
H6%f	7.1	7.1	7.1	48.8
H7%f	6.1	6.1	6.1	56.5
H8%f	8.1	8.0	8.1	65.1

HARMONICS TABLE — 0:59:25 — 09/05/14 12:51:35 — 1V 50Hz 3Ø WYE EN50160*

Volt	A	B	C	N
H1%f	100.0	100.0	100.0	100.0
H2%f	14.2	14.2	14.3	40.7
H3%f	20.5	20.4	20.3	53.8
H4%f	14.3	14.3	14.2	48.4

HARMONICS TABLE — 0:59:43 — 09/05/14 12:51:53 — 1V 50Hz 3Ø WYE EN50160*

Volt	A	B	C	N
H5%f	20.4	20.3	20.2	67.5
H6%f	31.5	31.5	31.4	97.6
H7%f	20.2	20.2	20.2	81.1
H8%f	31.3	31.3	31.3	125.7

HARMONICS TABLE — 0:42:09 — 09/05/14 12:34:19 — 1V 50Hz 3Ø WYE EN50160*

Volt	A	B	C	N
H1%f	100.0	100.0	100.0	100.0
H2%f	53.1	53.0	53.0	119.3
H3%f	32.6	32.6	32.6	120.6
H4%f	61.2	61.0	61.1	241.6

HARMONICS TABLE — 0:42:38 — 09/05/14 12:34:48 — 1V 50Hz 3Ø WYE EN50160*

Volt	A	B	C	N
H5%f	40.7	40.6	40.7	73.8
H6%f	59.9	59.8	59.8	117.7
H7%f	48.6	48.5	48.6	110.0
H8%f	31.3	31.2	31.3	84.3

Figure 4. Percentage values of the high-order harmonics in test signals measured by instrument - PQ analyzer Fluke 435

Here are only shown measured percentage values of individual voltage harmonics from 2nd to 8th high-order harmonics, which includes three test voltage signals generated with various levels of the harmonic disturbances, previously presented in Fig. 3.

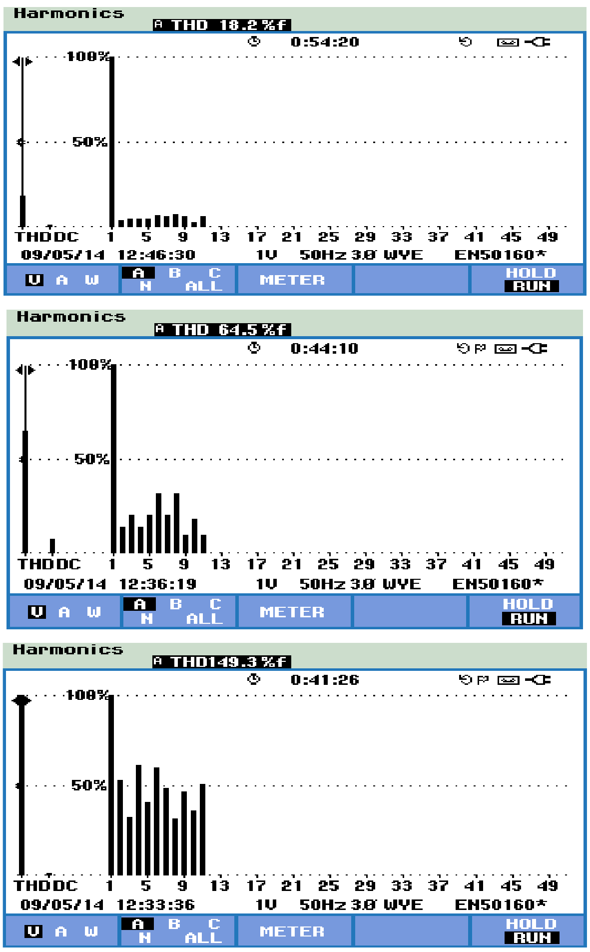


Figure 5. Recorded graphs of the measured high-order signal harmonics

Graphs of the measured percentage RMS values for 2nd to 11th high-order harmonics, recorded on a graphical display of the tested instrument for presented three test waveforms with certain level of the harmonic disturbances, are shown in Fig. 5. These graphs indicate maximum measured percentage values of individual high-order voltage harmonics in test waveforms. Percentage harmonic levels on instrument display, obtained by measurement procedure, fully correspond to defined harmonic values in test signal waveforms previously presented in Fig. 1.

Generally, developed LabVIEW based acquisition system for generation of the reference voltage signals is applicable in testing of the various instruments and equipment designed for measurement of the PQ parameters and network disturbances, defined according to relevant international quality standards.

IV. Conclusion

Acquisition system for generation of the reference voltage test waveforms with standard high-order harmonic disturbances is described in this paper. This software supported solution for signal generation, functionally based on LabVIEW application software, includes standard computer and acquisition board NI PCIe 6343. Basic purpose of this system is to provide standard signals applicable in testing of instruments for measurement of basic electrical power quality parameters and high-order signal harmonics, according to European quality standard EN 50160. Specific amplitude levels of the high-order harmonics in test voltage waveforms can be individually defined and generated. Continuous variation of the percentage amplitude level in input control section can be performed separately for each individual harmonic component or at the same time for all selected high-order harmonic components. Developed solution is practically verified by software controlled procedure applied to testing of instrument for measurement and processing of the high-order harmonic components – three-phase PQ analyzer Fluke 435 Series II. Some test waveforms and experimental measurement data, obtained by testing procedure, are presented in the paper.

ACKNOWLEDGMENT

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