Impulse-Calibration-System KAL 1000

Calibration-Software TRAS-KAL

according to IEC 61083-1, IEEE 1122 and IEC 60060-2, IEEE 4

DR. STRAUSS

Impulse Measurement
Calibration - Diagnosis
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Application

For the calibration and for performance tests and checks according to IEC 1083-1 und IEC-60-2 several calibration generators with high accuracy are required which are optimally adapted to the digital impulse voltage measuring system to be tested.

For this purpose a new family of precise calibration generators became developed including the necessary software to perform the required calibrations and tests in the high-voltage testfield in accordance with IEC 1083-1 and IEC 60-2 in an easy manner and in short time to save costs.

The impulse calibration system KAL 1000 is a modular system to perform tests on complete impulse voltage measuring systems and on digital recorders for the measurement of high impulse voltages and impulse currents. The modular design allows an optimal KAL-configuration depending on the actual application.

Additional, this modularity allows to upgrade or modify an existing KAL 1000 system in case of changing or additional requirements.

The technical design of the impulse calibration system KAL 1000 was done considering the international standards IEC 1083-1, Digital recorders for measurements in high-voltage impulse tests and the revision of IEC 60-2, at this time under consideration, the requirements for calibration generators in IEC 1083-1, Table 3 are fulfilled.

Calibration of Digital-Recorders according to IEC 1083-1

the calibration, performance check or performance test of the measuring ranges of the digital impulse voltage measuring systems TR-AS® according to IEC 61083-1 may be performed either by the method pulse calibration or alternatively by a separate calibration of voltage and time with a step voltage calibration and a time calibration.

Pulse Calibration

The pulse calibration is performed with help of the impulse calibration generators KAL-LI 0.84/60 (optional KAL-LI 1.56/60) for full and chopped lightning impulse voltage or with help of the impulse calibration generator KAL-SI 20/4000 for full or chopped switching impulse voltage.

The time-to-chopping can be set to any value from 0.1 µs to 10 000 µs including the standard chopping time of 0.5 µs.

Step Voltage Calibration

The step voltage calibration is performed with help of the impulse calibration generator KAL-STEP.

Time Calibration

The time calibration is performed with help of the time mark generator KAL-TIME.

Calibration-Software TRAS-KAL

The impulse calibration system KAL 1000 is controlled automatically by the digital impulse voltage measuring system TR-AS® with help of an inbuilt or completable relay.

The channels under calibration were connected separate or parallel to the respective output of the calibrator. After setting the d.c. charging voltage the calibration is done simultan on all channels for the selected measuring range.

With help of the control relay in the measuring system automatically the selected number of e.g. 20 measurements are performed and evaluated according to IEC 1083-1.

The mean value of the selected number of records and the largest deviation dedected is stored into a protocol-file for generation of the calibration certificate subsequently.

The Basic System includes the electronically controled d.c. voltage source with precise settable output voltage, available on a coaxial output and additional two measuring taps for control measuring with an calibrated external d.c. voltmeter.

In this way the calibration may be referenced to a National Standard, e.g. to an approved DKD-testlab or the PTB.

At the start of the automatic calibration procedur the value of this d.c. charge voltage must be input to the measuring system as reference level for the calculations.

Calibration Record

The calibration results of a KAL 1000 impulse calibrator with shapes STEP, ZEIT, LI, LIC und SI performed with an high-resolution digital impulse voltage measuring system TR-AS® 200-12 is documented in parts in the following calibration record:

Calibration STEP

Ch	Uo	Un	Usm	Fi	δm	StA	Max	MaxU	tmin	tmax
	V	V	V	Un/Usm	%	%	%	%	µs	µs
1	16	-15.89	-15.86	1.002	-0.16	0.06	0.62	0.10	0.25	1
1	50	-49.65	-49.48	1.003	-0.34	0.02	0.55	0.05	0.25	1
1	100	-99.3	-99.04	1.003	-0.26	0.02	0.60	0.03	0.25	1
1	500	-496.5	-495.5	1.002	-0.20	0.01	0.55	0.02	0.25	1
1	1000	-993	-986.9	1.006	-0.61	0.07	0.55	0.11	0.25	1
1	16	-16	-15.96	1.002	-0.22	0.07	0.23	0.13	0.42	8000
1	50	-50	-49.87	1.003	-0.27	0.02	0.24	0.04	0.42	8000
1	100	-100	-99.74	1.003	-0.26	0.02	0.24	0.03	0.42	8000
1	500	-500	-499.2	1.002	-0.17	0.01	0.24	0.02	0.42	8000
1	1000	-1000	-995.5	1.004	-0.45	0.02	0.29	0.05	0.42	8000

Calibration LI 0.84/60

Ch	Uo	Un	Usm	δm	StA	T1n	T1	δm	StA	T2n	T2	δm	StA
	V	V	V	%	%	µs	µs	%	%	µs	µs	%	%
1	50	48.84	48.6	-0.48	0.02	0.839	0.832	-0.88	0.11	60.2	60.4	0.32	0.04
1	55	53.71	53.43	-0.52	0.04	0.836	0.829	-0.88	0.10	60.0	60.3	0.56	0.04
1	75	73.36	73	-0.49	0.02	0.834	0.824	-1.20	0.10	60.1	60.3	0.29	0.05
1	110	107.3	107.1	-0.22	0.02	0.835	0.828	-0.82	0.10	60.0	60.3	0.55	0.02
1	150	146.4	145.9	-0.33	0.02	0.836	0.828	-0.95	0.09	60.2	60.3	0.20	0.05
1	220	214.9	214.1	-0.35	0.03	0.839	0.830	-1.11	0.09	60.0	60.3	0.54	0.04
1	300	292.8	292.1	-0.24	0.01	0.841	0.831	-1.20	0.07	60.2	60.4	0.38	0.06
1	440	429.2	428.7	-0.11	0.03	0.840	0.832	-0.90	0.12	60.1	60.4	0.44	0.03
1	600	585.5	584.6	-0.15	0.02	0.841	0.834	-0.85	0.09	60.3	60.4	0.14	0.05
1	750	731.8	730.1	-0.24	0.02	0.843	0.836	-0.81	0.10	60.4	60.5	0.17	0.06
1	900	877.9	875.4	-0.29	0.03	0.843	0.836	-0.78	0.13	60.5	60.6	0.09	0.05
1	1000	976	972.7	-0.33	0.02	0.846	0.838	-0.95	0.07	60.1	60.6	0.88	0.03
1	50	-48.78	-48.58	-0.41	0.03	0.835	0.830	-0.64	0.10	60.0	60.1	0.19	0.02
1	55	-53.66	-53.43	-0.44	0.02	0.833	0.825	-0.94	0.07	59.9	60.2	0.44	0.03
1	75	-73.25	-72.98	-0.36	0.02	0.828	0.819	-1.07	0.09	59.9	60.1	0.27	0.04
1	110	-107.2	-106.9	-0.24	0.03	0.827	0.821	-0.71	0.13	59.9	60.1	0.34	0.05
1	150	-146.3	-145.8	-0.32	0.02	0.831	0.824	-0.81	0.11	60.0	60.2	0.36	0.05
1	220	-214.6	-214.1	-0.22	0.03	0.834	0.828	-0.75	0.11	59.9	60.1	0.41	0.04
1	300	-292.4	-292.1	-0.10	0.03	0.835	0.829	-0.72	0.12	60.1	60.2	0.22	0.04
1	440	-428.8	-428.7	-0.02	0.01	0.837	0.829	-0.96	0.08	60.0	60.2	0.41	0.04
1	600	-584.9	-584.3	-0.10	0.02	0.838	0.830	-0.98	0.07	60.2	60.2	0.07	0.03
1	750	-730.8	-729.7	-0.16	0.04	0.839	0.832	-0.85	0.15	60.2	60.4	0.33	0.06
1	900	-876.8	-875	-0.21	0.02	0.840	0.834	-0.71	0.08	60.2	60.4	0.28	0.04
1	1000	-973.9	-971.7	-0.23	0.02	0.841	0.834	-0.79	0.13	60.0	60.5	0.91	0.10

Calibration LIC

Ch	Uo	Un	Usm	δm	StA	T1n	T1	δm	StA	TCn	TC	δm	StA
	V	V	V	%	%	µs	µs	%	%	µs	µs	%	%
1	100	76.4	76.68	0.36	0.06					0.502	0.506	0.84	0.06
1	200	150.5	150.9	0.28	0.08					0.498	0.501	0.52	0.05
1	300	225.3	226.1	0.35	0.08					0.500	0.501	0.36	0.04
1	400	300.2	301.4	0.40	0.06					0.501	0.503	0.41	0.03
1	600	450.7	453.5	0.61	0.07					0.503	0.505	0.45	0.05
1	800	600.8	603.8	0.50	0.05					0.503	0.506	0.51	0.02
1	1000	750.6	751.9	0.17	0.05					0.503	0.504	0.28	0.03
1	100	-76.48	-76.88	0.53	0.10					0.501	0.505	0.82	0.06
1	200	-150.7	-151.2	0.36	0.07					0.495	0.498	0.69	0.13
1	300	-225.8	-226.9	0.49	0.05					0.498	0.501	0.67	0.04
1	400	-300.8	-302.5	0.58	0.06					0.501	0.503	0.47	0.03
1	600	-451.7	-454.8	0.69	0.06					0.502	0.505	0.57	0.03
1	800	-600.3	-605	0.78	0.08					0.500	0.503	0.65	0.05
1	1000	-747.6	-750	0.32	0.06					0.497	0.498	0.20	0.04

Calibration SI 250/2500

Ch	Uo	Un	Usm	δm	StA	T1pn	T1p	δm	StA	T2n	T2	δm	StA
	V	V	V	%	%	µs	µs	%	%	µs	µs	%	%
1	50	42.33	42.56	0.54	0.03	247.60	249.000	58	0.16	2524.0	2530.0	0.24	0.09
1	100	84.71	85.11	0.47	0.02	247.40	248.800	55	0.10	2526.0	2532.0	0.22	0.03
1	500	422.9	426	0.74	0.04	247.70	248.400	28	0.11	2529.0	2532.0	0.13	0.06
1	1000	845.6	851.3	0.67	0.03	246.90	248.700	75	0.09	2537.0	2532.0	-0.19	0.09
1	50	-42.26	-42.42	0.38	0.04	247.20	248.400	47	0.07	2504.0	2502.0	-0.09	0.05
1	100	-84.46	-84.85	0.47	0.02	247.00	248.000	39	0.11	2499.0	2504.0	0.18	0.06
1	500	-421.6	-425	0.80	0.02	247.00	248.100	43	0.06	2503.0	2505.0	0.10	0.06
1	1000	-843.8	-848.6	0.57	0.02	246.90	248.000	44	0.13	2512.0	2508.0	-0.16	0.05

Calibration TIME

Ch	Range	Time interval	δm	StA	Max
	V	µs	%	%	%
1	25	20000	0.0008	0.0001	0.0001

Ch	Range	Time interval	δm	StA	Max
	V	µs	%	%	%
1	10	20000	0.0138	0.0001	0.0001

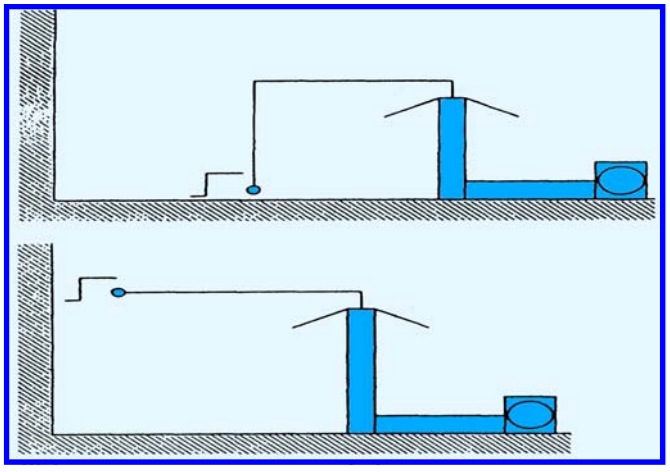
Calibration of Impulse-Measuring-Systems according to IEC 60-2

The automatic controlled calibration of the complete measuring system comprising the impulse voltage divider, the neccessary leads, the measuring cable and the digital impulse voltage measuring system TR-AS®, follows by the parameter method with help of the unit-step-voltage-generator RIG 1000 and the calibration software TRAS-TEIL.

Unit-Step-Voltage-Generator RIG 1000

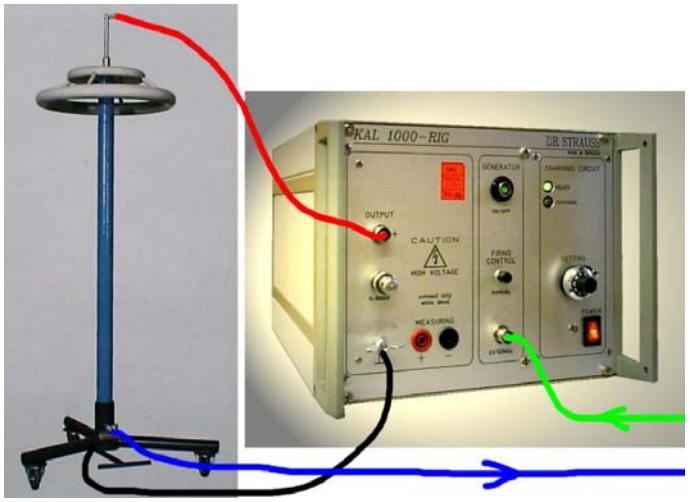
At the parameter method, applicable for performance check or test, the impulse scale factor and the time parameters of the measuring system are determined by measuring and evaluating the step response of the measuring system. The result can be compared with the manufacturers specification or with performance tests or checks performed in the past.

For automatically calibration and generation of an calibration report the powerful software TRAS-TEIL with menu-oriented operations is available.



Test setup according to IEC 60-2

The determination of the impulse scale factor and the response parameters of the complete measuring system according to IEC 60-2 is done with the unit step voltage generator RIG 1000 using a repetitive sampling methode included in the software TRAS-TEIL, which allows sampling rates of 1 to 5 GHz corresponding to sampling intevals of 1 ns downto 200 ps with our digital recorders TR-AS®.

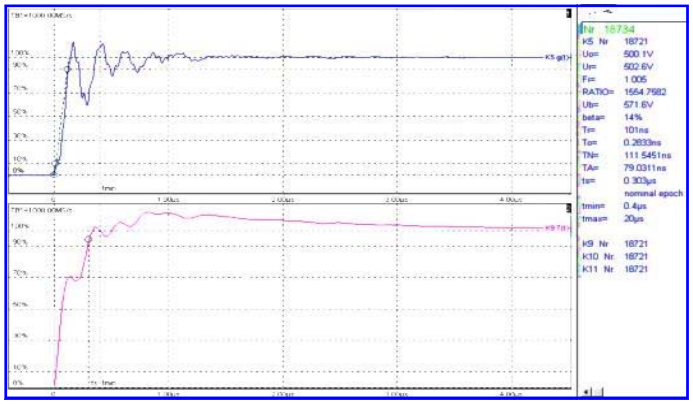


The unit step voltage generator RIG 1000 is controlled automatically by the digital impulse voltage measuring system TR-AS® with help of an inbuilt or completable relais.

For example, the performance check of an 3 MV impulse voltage divider in the h.v. testfield of an big transformer manufacturer was performed, the test results are shown in the following.

First of all the step response g(t) is measured, whereby a sampling rate of 1 GHz corresponding to 1 ns time resolution yields a satisfying accuracy within a short testing time.

The response parameter of the measured step response g(t) and the time behavior of the response time T(t) by integration of the function 1-g(t) automatically is calculated by the AT-computer inside the measuring system.



Calibration of a 3 MV impulse voltage divider in a big transformer testfield

The evaluation of the response time T(t) follows inside of an selectable time intervall tmin to tmax

divider performence check

PARAMETER	ref val.	dim	act. val.	dim	difference [%]		tolerance [%]	accepted
F	1.00		1.00		-0.01	±	1.00	YES
beta	14.00	%	14.00	%	0.00	±	30.00	YES
ts	0.30	µs	0.30	µs	0.00	±	20.00	YES
Ta	79.03	ns	78.16	ns	-1.10	±	20.00	YES
tr	101.00	ns	100.00	ns	-0.99	±	20.00	YES
T0	0.28	ns	0.30	ns	4.20	±	20.00	YES
TN	111.55	ns	110.63	ns	-0.82	±	20.00	YES

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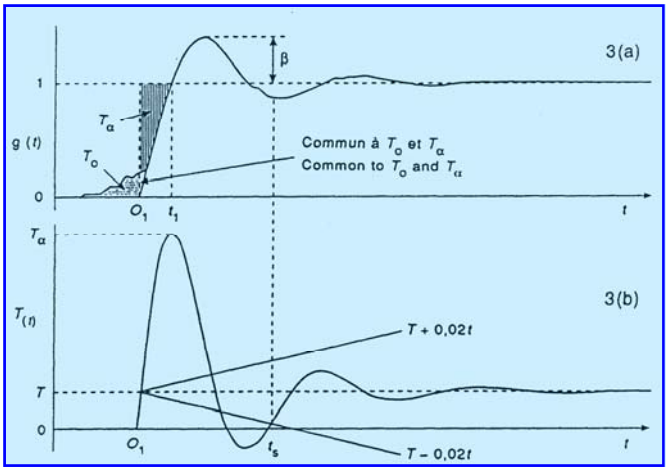
The calibration report includes the test results of the reference measurement REF in the past as also the actual test results of the AMS (approved measuring system). For each individual parameter the actual difference AMS/REF-1 is calculated and then compared with an earlier specified accepted differenc. The test result "accepted" or "not accepted" automatically is written to the rightmost column.

E.g., the determination of the impulse scale factor shows in the selected time interval 0.4 - 20.0 µs negligible deviations from the specified value of the manufacturer. The scale



Definition of response parameters and settling time

The calculated results of the measurment are:

ß	overshoot
F	actual impulse scale factor
O1	virtual origin, set to t=0
To	initial distortion time
Ta	partial response time
TN	experimental response time at t=tmax
ts	settling time
tmin	begin of evaluation
tmax	end of evaluation

For automatically determination of the settling time the limiting functions T ± 0.02t are calculated and displayed together with the response time T(t). The latest point of intersection of T(t) with the limiting functions is the wanted settling time according to IEC 60-2.

Calibrator Basic-Device KAL 1000

for supply and control of the KAL-Generators described below, rack mount with power supply, line filter, built into a 19" housing

design	cassette	4 HE, 42 TE
	housing (BxHxD)	500x200x320 mm
	or 19" rack mount	
weight	approx. 10 kg	

H.V. Load Circuit, electronically controled

design		in basic device
charge voltage, adjustable		
with 10-turn-potentiometer		0 - +1000 V positiv
	setting-accuracy	< 0.1 %
digital display	LED	0-1000.0 V
	measuring-accuracy	± 0.1 % ± 2 digit
charge time	modul-dependent	1 .. 10 s
output	frontside	coaxial
	measurement	2 plugs
max. cable length	unlimited	
load resistance		>= 200 kOhm

Control Electronic

design		in basic device
releasing	manual	key
	BNC-input	TTL LO-level or external relais
impulse output	switching gap SG	5 Vp, BNC
time-to-chopping	adjustable	0.1 - 10 000 µs
	step	0.1 µs
	quarz-timebase	10 MHz, 100 ppm
impulse output	chopping gap CG	5 Vp, BNC

Step-Voltage-Generator KAL-STEP

for the step calibration of the inputs of digital impulse voltage measuring system according to IEC 1083-1

design		in basic device	
charge voltage	base-device	0 .. +1000 V	
switching-device	electronically		
	output	short-circuited	
	falltime	< 10 ns (90/10%)	
impulse output	BNC	10 .. 1000 V	
	polarity	negative step	
	output-resistance	50 Ohm	
	load-resistance	>= 200 kOhm	
	cable-length	1,5 m	
accuracy	step-voltage	± 0.5% / ± 0.2%	1)

Lightning-Impulse-Generator KAL-LI 0.84/60

for pulse calibration of the digital impulse voltage measuring system according to IEC 1083-1

design		cassette 12 TE	
charge voltage	basic-device	0 - +1000 V	
	switching-device	electronically	
	chopping-device	electronically	
	charge-capacity	0.6 µF	
impulse output	BNC	±50 .. ±1000 V	2)
	output-resistance	20 Ohm	
	cable-length	1,5 m	
shape	standard	0.84/60 µs	
	optional	1.56/60 µs	
chopping time	selectable	0.1 .. 10 000 µs	
accuracy	peak-voltage	± 1% / ± 0.2%	1)
	front-time	± 2% / ± 0.5%	1)
	time-to-half-value	± 2% / ± 0.2%	1)
	time-to-chopping	± 2% / ± 1%	1)
	according to	IEC 1083-1 table 3	

Switching-Impulse-Generator KAL-SI 20/4000

for pulse calibration of the digital impulse voltage measuring system according to IEC 1083-1.

design		cassette 12 TE	
charge voltage	basic-device	0 - +1000 V	
	switching-device	electronically	
	chopping-device	electronically	
	charge-capacity	1 µF	
impulse output	BNC	±50 .. ±1000 V	2)
	output-resistance	20 Ohm	
	cable-length	1.5 m	
shape	standard	20/4000 µs	
	optional	250/2500 µs	
chopping time	selectable	0.1 .. 10 000 µs	
accuracy	peak-voltage	± 1% / ± 0.2%	1)
	time-to-peak	± 2% / ± 0.2%	1)
	time-to-half-value	± 2% / ± 0.2%	1)
	time-to-chopping	± 2% / ± 1%	1)
	according to	IEC 1083-1 table 3	

Timemark-Generator KAL-ZEIT

For time calibration of the digital impulse voltage measuring system according to IEC 1083-1.

design		in base device
	time-intervall	20 ms ±0.01%
output BNC	squarewave	0 / 5 V, TTL-level

Unit-Step-Voltage-Generator RIG 1000 (H)

for determination of the impulse scale factor and the response parameters of the high voltage impulse measuring system with the unit step method according to IEC 60-2. The generator is placed on the floor or wall in the h.v. testfield and connected to the h.v. divider.

design	cassette	4 HE, 42 TE
	housing (BxHxD)	260x200x320 mm
weight	approx. 4 kg	
charge voltage	coax-input	0 - +1000 V
	feeding	basic device via coaxcable 20 m
type H	optionally	inbuilt h.v. supply
Charge capacitor	charge-capacity	5.3 µF
switching-device		electronically
	output-resistance	2 Ohm
	risetime	< 10 ns (10/90%)
releasing	BNC-input	TTL LO-level or relay (meas.system) via coaxcable 20 m
impulse output		0 .. ±1000 V
	polarity	positive or negative
	connection	to i.v. divider
	load	>= 5 kOhm || 10 nF
accuracy	peak value	± 0.1% stat.
power supply		battery inside

1) long term stability / short term stability
2) efficiency < 1
Technical data and design subject to modification without notice.

wave form	chopping time	output voltage range	for input range
full wave lightning impulse LI 0,84/60	100 ns—20 ms	±50 V to ±1000 V	50 V - 2500 V
front-chopped lightning impulse, Tc=500ns	500 ns	±50 V to ± 750 V	100 V - 1800 V
switching impulse SI 20/4000	100 ns—20 ms	±50 V to ±1000 V	50 V - 2500 V
switching impulse SI 250/2500	100 ns—20 ms	±50 V to ±1000 V	50 V - 2500 V
STEP Voltage		10 V to 1000 V	10 V - 2500 V

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