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IEC 61439: Alternate Design Verification Methods

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Abstract

Design verification for low-voltage power switchgear and control gear assemblies is intended to verify compliance of the design of an assembly or assembly system with the requirements of IEC61439 series of standards. There are 3 methods of verification. 1. Verification testing 2. Verification comparison with a tested reference design 3. Verification assessment by calculations and design rules including use of appropriate safety margins. The normally preferred verification method is verification by testing. However, verification by assessment and verification by comparison are also alternate verification methods provided by IEC 61439, which are still unexplored. This is in spite of the fact that IEC 61439 states: "*all the permitted means of design verification which includes comparison and assessment are equivalent in terms of performance achieved.*" Here, we shall elaborate on the verification assessment and verification comparison methods for Low voltage switchgear and control gear assemblies.

Keywords: Assessment, Assembly, Comparison, Low Voltage Switchgear, Testing, Verification

1. Verification Assessment

Design verification by strict design rules or calculations applied to a sample of an assembly or to parts of assemblies to show that the design meets the requirements of the relevant assembly standard.

When there is more than one method for the same verification, they are considered equivalent and the selection of the appropriate method is the responsibility of the original manufacturer.

However, all the tests are not possible with assessment. Annex D of IEC 61439-1 mentions the verification options available and applicable against each tests.

Let's discuss about the tests which are possible by assessment.

1.1 Glow Wire Test

Verification of resistance of insulating materials to abnormal heat and fire due to internal electric effects:

- 960 °C for parts necessary to retain current-carrying parts in position.
- 850 °C for enclosures intended for mounting in hollow walls.

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Annex D
(informative)

Design verification

Table D.1 – List of design verifications to be performed

No.	Characteristic to be verified	Clauses or subclauses	Verification options available: Testing	Comparison with a reference design	Assessment
1	Strength of material and parts:	10.2			
	Resistance to corrosion	10.2.2	YES	NO	NO
	Properties of insulating materials:	10.2.3			
	Thermal stability	10.2.3.1	YES	NO	NO
	Resistance to abnormal heat and fire due to internal electric effects	10.2.3.2	YES	NO	YES
	Resistance to ultra-violet (UV) radiation	10.2.4	YES	NO	YES
	Lifting	10.2.5	YES	NO	NO
	Mechanical impact	10.2.6	YES	NO	NO
	Marking	10.2.7	YES	NO	NO
2	Degree of protection of enclosures	10.3	YES	NO	YES
3	Clearances	10.4	YES	NO	NO
4	Creepage distances	10.4	YES	NO	NO
5	Protection against electric shock and integrity of protective circuits:	10.5			
	Effective continuity between the exposed conductive parts of the ASSEMBLY and the protective circuit	10.5.2	YES	NO	NO
	Short-circuit withstand strength of the protective circuit	10.5.3	YES	YES	NO
6	Incorporation of switching devices and components	10.6	NO	NO	YES
7	Internal electrical circuits and connections	10.7	NO	NO	YES
8	Terminals for external conductors	10.8	NO	NO	YES
9	Dielectric properties:	10.9			
	Power-frequency withstand voltage	10.9.2	YES	NO	NO
	Impulse withstand voltage	10.9.3	YES	NO	YES
10	Temperature-rise limits	10.10	YES	YES	YES
11	Short-circuit withstand strength	10.11	YES	YES	NO
12	Electromagnetic compatibility (EMC)	10.12	YES	NO	YES
13	Mechanical operation	10.13	YES	NO	NO

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- 650 °C for all other parts, including parts necessary to retain the protective conductor.

Assessment: As an alternative, to the testing the original manufacturer shall provide data on the suitability of materials from the insulating material supplier to demonstrate compliance with the requirements.

1.2 Resistance to Ultra-violet (UV) Radiation

This test applies only to enclosures, external parts of assemblies intended to be installed outdoors, and which are constructed of insulating materials or metals that are entirely coated by synthetic material. Representative samples of such parts shall be subjected to the following test:

Assessment: This test need not be carried out if the original manufacturer can provide data from the material supplier to demonstrate that material of the same type and thickness or thinner compiles with this requirement.

1.3 Degree of Protection

Testing: The degree of protection shall be verified in accordance with IEC 60529; the test may be carried out on one representative equipped assembly in a condition stated by the original manufacturer.

Assessment: Where an empty enclosure in accordance with IEC 62208 is used, a verification assessment shall be performed to ensure that any external modification that has been carried out does not result in a deterioration of the degree of protection; In this case, no further testing is required.

1.4 Impulse withstand Voltage

Testing: The 1, 2/50 μs impulse voltage shall be applied to the assembly five times for each polarity at intervals of 1s minimum.

Table 1 – Minimum clearances in air [a] (8.3.2)

Rated impulse withstand voltage U_{imp} kV	Minimum clearance mm
≤ 2,5	1,5
4,0	3,0
6,0	5,5
8,0	8,0
12,0	14,0
[a] Based on inhomogeneous field conditions and pollution degree 3.	

Assessment: Clearances shall be verified by measurement, or verification of measurements on design drawings, employing the measurement methods stated in Annex F. The clearance shall be at least 1.5 times the value specified in Table 1. If the clearance is more than 1.5 times than required value, impulse test is not required.

1.5 Temperature Rise

Assessment: Two calculation methods are provided by standard for specific ratings. Both determine the approximate air temperature rise inside the enclosure, which is caused by the power losses of all circuits, and compare this temperature with the limits for the installed equipment.

Method 1) Single compartment assembly with rated current not exceeding 630 A

Verification of the temperature rise of a single compartment ASSEMBLY with the total supply current not exceeding 630 A and for rated frequencies up to and including 60 Hz may be made by calculation if all the following conditions are fulfilled:

The power loss data for all built-in components is available from the component manufacturer;

There is an approximately even distribution of power losses inside the enclosure;

The rated current of the circuits of the ASSEMBLY to be verified shall not exceed 80% of the rated convectional free air thermal current (Ith) If any, or the rated current (ln) of the switching devices and electrical components included in the circuit. Circuit protection devices shall be selected to ensure adequate protection to outgoing circuits, e.g. thermal motor protection devices at the calculated temperature in the ASSEMBLY;

a) The mechanical parts and the installed equipment are so arranged that air circulation is not significantly impeded.
b) Conductors carrying currents in excess of 200A, and the adjacent structural parts are so arranged that eddy-current and hysteresis losses are minimized.
c) All conductors shall have a minimum cross-sectional area based on 125 % of the permitted current rating of the associated circuit.
d) The temperature rise depending on the power loss installed in the enclosure for the different installation methods.

The effective power losses of all circuits including interconnecting conductors shall be calculated based on rated current of the circuits. The total power loss of the assembly is calculated by adding the power losses of the circuits taking additionally into account that the total load current is limited to the rated current of the ASSEMBLY. The power losses of the conductors are determined by calculation.

The temperature rise within the ASSEMBLY is then determined from the total power loss.

Determination of the Power Loss Capability of an Enclosure by Test

The power loss shall be simulated by means of heating resistors that produce heat equivalent to the intended power loss capability of the enclosure. The heating resistors shall be distributed evenly over the height of the enclosure and installed in suitable places inside the enclosure. The cross-section of the leads to these resistors shall be such that no appreciable amount of heat is conducted away from the enclosure.

The test shall be carried out and the air temperature rise shall be measured in the top of the enclosure. Enclosure temperatures shall not exceed the values given by TR limit as per IEC61439.

The ASSEMBLY is verified if the air temperature determined from the calculated power loss does not exceed the permissible operating air temperature as declared by the device manufacturer. This means for switching devices or electrical components in the main circuits that the continuous load does not exceed its permissible load at the calculated air temperature and not more than 80% of its rated current.

Method 2) Assembly with rated current not exceeding 1600 A

Verification of the temperature rise of a single or multiple compartment ASSEMBLY with the total supply current not exceeding 1600A and for rated frequencies up to and including 60 Hz, may be made by calculation in accordance with the method of IEC 60890 if all the following conditions are fulfilled:

Points a) to e) of METHOD 1 plus the following:

f) All conductors shall have a minimum cross-sectional area based on 125% of the permitted current rating of the associated circuit. Selection of cables shall be in accordance with IEC 60364-5-52. Examples on how to adapt this standard for conditions inside an ASSEMBLY are given in Annex H. The cross-section of bars shall be as tested or as given in Annex N. Where the device manufacturer specifies a conductor with a larger cross-sectional area, this shall be used.
g) For enclosures with natural ventilation, the cross-section of the air outlet openings is at least 1.1 times the cross section of the air inlet openings.
h) There are no more than three horizontal partitions in the ASSEMBLY or a section of an ASSEMBLY.
i) For enclosures with compartments and natural ventilation, the cross section of the ventilating openings in each horizontal partition is at least 50% of the horizontal cross section of the compartment.

The effective power losses of all circuits including interconnecting conductors shall be calculated based on rated current of the circuits. The total power loss of the ASSEMBLY is calculated by adding the power losses of the circuit taking additionally into account that the total load current is limited to the rated current of the ASSEMBLY. The power losses of the conductors are determined by calculation (Annex H).

The temperature rise within the ASSEMBLY is then determined from the total power loss using the method of IEC 60890.

The ASSEMBLY is verified if the calculated air temperature at the mounting height of any device does not exceed the permissible ambient air temperature as declared by the device manufacturer.

This means for switching devices or electrical components in the main circuits that the continuous load does not exceed its permissible load at the calculated local air temperature and not more than 80% of its rated current (see10.10.4.3.1 c).

1.6 EMC

Assessment: No EMC immunity or emission tests are required on final ASSEMBLIES if the following conditions are fulfilled:

a) The incorporated devices and components are in compliance with the requirements for EMC for the stated environment (see J.9.4.1) as required by the relevant product or generic EMC standard.
b) The internal installation and wiring is carried out in accordance with the devices and components manufacturer's instructions (arrangement with

regard to mutual influences, cable, screening, earthling etc.)

2. Verification Comparison

2.1 Temperature Rise

Standard defines how the rated currents of variants can be verified by derivation from similar arrangements verified by test.

1) Temperature-rise tests on the circuit(s) carried out at 50 Hz are applicable to 60 Hz for rated currents up to and including 800A. In the absence of tests at 60 Hz for currents above 800A, the rated current at 60 Hz shall be reduced to 95% of that at 50Hz. alternatively, where the maximum temperature rise at 50 Hz does not exceed 90% of the permissible value, then derating for 60 Hz is not required. Tests carried out at a particular frequency are applicable at the same current rating to lower frequencies including d.c.
2) Assemblies verified by derivation from a similar tested arrangement shall comply with the following:
   a\` The functional units shall belong to the same group as the functional unit selected for test
   b) The same type of construction as used for the test
   c) The same or increased overall dimensions as used for the test
   d) The same or increased cooling conditions as used for the test (forced or natural convection, same or larger ventilation openings)
   e) The same or reduced internal separations as used for the test (if any)
   f) The same or reduced power losses in the same section as used for the test
3) Thermal tests performed on 3-phase, 3-wire assemblies are considered as representing 3-phase, 4-wire and single-phase, 2-wire or 3-wire assemblies, provided that the neutral conductor is sized equal to or greater than the phase conductors arranged in the same manner.
4) Busbars: Ratings established for aluminum busbars are valid for copper Busbars with the same cross sectional dimensions and configuration. However, ratings established for copper busbars shall not be used to establish ratings of aluminum busbars.
4) The ratings of variants not selected for test shall be determined by multiplying their cross-section with the current density of a larger cross-section busbar of the same design that has been verified by test.
5) If additionally, a similar cross-section than the one to be derived has been tested, which also fulfils the conditions, then the rating of the intermediate variants may be established by interpolation.
6) The standard allows, in clearly defined circumstances, for the derivation of rating of a double lamination busbar has been established by test, it is acceptable to assign a rating equal to 50% of the tested arrangement to a busbar comprising a single lamination with the same width and thickness as the tested laminations, when all other considerations are the same.

Functional units - Device substitution

A device may be substituted with a similar device from another series to that used in the original verification, provided that the power loss and terminal temperature rise of the device, t=when tested in accordance with its product standard, is the same or lower. In addition, the physical arrangement within the functional unit and the rating of the functional unit shall be maintained.

2.2 Short Circuit

Short circuit verification by comparison can be done in two ways

a) Using a check list:

Item No.	Requirements to be considered
1	Is the short-circuitwithstand rating of each circuit of the assembly to be assessed, less than or equal to, that of the reference design?
2	Is the cross-sectional dimensions of the busbars and connections of each circuit of the assembly to be assessed, greater than or equal to, those of the reference design?
3	Is the center line spacing of the busbars and connections of each circuit of the assembly to be assessed, greater than or equal to, those of the reference design?
4	Are the busbar supports of each circuit of the assembly to be assessed of the same type, shape and material and have, the same or smaller center line spacing, along the length of the busbar as the reference design? And is the mounting structure for the busbar supports of the same design and mechanical strength?

5	Are the material and the material properties of the conductor of each circuit of the assembly to be assessed the same as those of the reference design?
6	Are the short-circuit protective devices of each circuit of the assembly to be assessed equivalent, that is of the same make and series with the same or better limitation characteristics based on the device manufacturer's data, and with the same arrangement as the reference design?
7	Is the length of unprotected live conductors, of each non-protected circuit of the assembly to be assessed less than or equal to those of the reference design?
8	If the assembly to be assessed include an enclosure, did the reference design include an enclosure when verified by test?
9	Is the enclosure of the assembly to be assessed of the same design, type and have at least the same dimensions of that of the reference design?
10	Are the compartments of each circuit of the assembly to be assessed of the same mechanical design and at least the same dimensions as those of the reference design?

If assembly is meeting the entire above requirement, then no testing is required.

b) Using a calculation:

As per this clause of IEC, if there is a tested assembly available (referred to as TS or tested structure, then using calculations provided in the standard IEC 60865, we can qualify the untested assembly (referred to as NTS or non-tested structure). It states that the short-circuit withstand strength of NTS is verified from TS by applying calculations according to IEC 60865-1 to both structures. The short-circuit withstand strength of the NTS is considered verified if the calculations show that the NTS does not have to withstand higher mechanical and thermal stresses than the tested structure.

This method can be used after allowing the following conditions to be met:

1) SC current can be changed only to lower values
2) Calculated temperature rise of NTS during short circuit should not be more than TS
3) Changes of material or shape of supports is not allowed. Other supports can be used, however, they must have been tested previously to meet the required mechanical strength
4) The type of busbars and equipment connections have been previously verified by test
5) IEC 60865 can only be used for straight busbars. However, for angular busbars the calculations can still be done, considering angular busbars to be a set of straight busbars with supports and the bending corners.

2.3 Illustrative Example

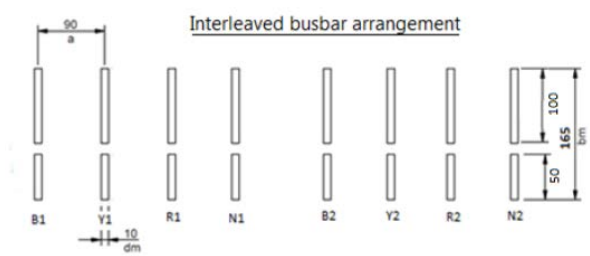
Panel Specification	4000 A Type-tested design	3200 A derived design
Busbar cross-section (sq.mm)	X	Y
Rated current (A)	4000	3200
Rated frequency (Hz)	50	
Rated short-time withstand current	80 kA for 1 s	65 kA for 1 s
Degree of protection	IP 43	
Ambient temperature (°C)	50	
Panel configuration in (mm)	H_1 X W_1 X D_1	H_2 X W_2 X D_2

Annex 1: Verification of Temperature-rise limits of assembly through comparison with a tested reference design

- Functional units of same group
- Same or lesser current density
- Same type of construction
- Same or higher volume of enclosure
- Same or reduced internal separation
- Same or reduced power losses in the same section as used for the test
- Thermal influences of the adjacent units are not more severe

Verification of temperature rise inside the switchboard $Z = \frac{(b_m * (d_m\text{^}3))}{12\,(d_m/2)}$ **as per IEC 60890.**

Inference: The temperature-rise inside the panel is less in 3200 A arrangements with reference to 4000 A type tested design



Annex 2: Verification of short circuit support span for 80 kA as per IEC 60865 from 100 kA type-tested design

Step 1: Calculation of section-modulus of the conductor (**Z**)

Step 2: Calculation of Peak value of force between conductors during 3-Ø short-circuit ($\mathbf{F}_{m3}$)

Step 3: Calculation of bending stress caused by forces between conductors ($\boldsymbol{\sigma}_m$)

Step 4: Comparison of stress of type-tested design against the design to be derived and acceptable stress value of the conductor material

$$\sigma_m = V_\sigma V_r \beta \frac{F l}{8 Z}$$

where,

b_m is total conductor width

d_m is conductor thickness

where,

i_{p3} is peak value of short-circuit current

l is maximum centre-centre distance between supports

a_m iseffective distance between conductors

Figure caption

where,

$F = F_{m3}$ – Peak value of forces between conductors

$V_\sigma V_r = 1$ for three phase fault without automatic reclosing

$\beta = 0.73$ for simple supported structure with 2 or more span

Z is the section modulus of the conductor

Calculation:

Section modulus $Z = 2.75 \times 10^{-6}$

Case 1: 100 kA type-tested design

Force on busbar for 100 kA, $\mathbf{F}_{m3} = 8029.485$ N

Stress on busbar for 100 kA, $\boldsymbol{\sigma}_{m1} = 106573165$ N/m^2

Case 2: 80 kA derived design

Force on busbar for 80 kA, $\mathbf{F}_{m3} = 7707.4$ N

Stress on busbar for 80 kA, $\boldsymbol{\sigma}_{m2} = 153447327$ N/m^2

Inferences:

- Force $\mathbf{F}_{m3}$ of 80 kA derived design is lesser than force $\mathbf{F}_{m3}$ of 100 kA type-tested design
- Stress $\boldsymbol{\sigma}_{m2}$ of 80 kA derived design is higherthanstress $\boldsymbol{\sigma}_{m1}$ of 100 kA type-tested design

However, conductors are assumed to withstand the short-circuit forces if,

$\boldsymbol{\sigma}_m \leq \mathbf{q}\, \mathbf{R}_{p0.2}$ (Equation 11 of IEC 60865-1)

where,

q = 1.5 for rectangular conductors

$R_{p0.2}$ = stress corresponding to yield point

Acceptable stress value,

$\boldsymbol{\sigma}_m < (1.5 * 245000000)$ N/m^2

Stress on busbar $\boldsymbol{\sigma}_{m1}$ & $\boldsymbol{\sigma}_{m2}$ < 367500000 N/m^2

Hence, the derived assembly is suitable for the short-circuit force of 80 kA with the given span.

3. Conclusion

Although for many decades, testing has been the most popular method for verification of performance characteristics of a switchgear assembly, there is a visible change in trend. International Standard bodies like IEC are also emphasizing on calculations and comparisons as an alternate and 'performance equivalent' methods to testing. These methods need to be studied and evaluated in detail by all parties, including OEMs, panel builders, consultants and end users before deciding on performing an actual lab test, to see if there can be an alternate method of verifying a switchgear assembly. This will result in saving time and costs involved in actual physical testing, albeit without compromising on the final product quality.

4. References

1. IEC 61439-1, 2 2011 Ed. 2
2. IEC 60890 Ed.2
3. IEC 60865-1