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Changes within IEC 61439-1 & 2 Ed 3

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Version 1

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Executive summary

After nine years of committee debate the 3rd Editions of IEC 61439-1 and IEC 61439-2, the standards for power switchgear and controlgear assemblies, have been published. The new editions include changes, the significance of which will affect the way assemblies are specified and used. All the changes are either a recognition of the changing needs of assemblies in the market, technical advances, further options in design verification or clarifications. These changes have been made with simple objectives in mind; ensuring assemblies are fit for purpose and there is a clear understanding of the capabilities of the assembly between specifier and manufacturer.

The more significant changes include:

a. An annex dealing with the specific requirements of assemblies used in photovoltaic applications; where environmental and operating conditions are harsher than that for typical assemblies.

b. A recognition that, whilst the possibility of an arcing fault within a well-designed and manufactured assembly is extremely remote, for safety and operational reasons, some users wish to reduce the risk even further.

c. A greater focus on DC assemblies to reflect the wider use of DC in photovoltaic applications, battery storage systems and the increasing interest in use of DC distribution networks.

d. Closer links with the installation rules by the introduction of a new characteristic, 'group rated current of a circuit of an assembly'. This aligns closely with the design current of a circuit within an electrical installation. It is the most significant of all the changes and needs to be clearly understood to avoid misunderstandings. Specifiers are encouraged to provide the design current of each circuit and make the assembly manufacturer fully responsible for ensuring the assembly can deliver the necessary load currents, without overheating.

e. A distinction between the 'macro' environment outside the assembly, for which the assembly as a whole must be suitable, and the 'micro' environment inside the assembly, which must be suitable for the devices enclosed within the assembly.

f. Requirements to ensure insulating materials will not unacceptably age during the intended life of the assembly.

g. New temperature-rise verifications without testing the actual arrangements for actively cooled assemblies and circuits within larger assemblies.

h. Recognition of Class I and Class II assemblies for electrical installations with different fault protection arrangements.

Economic and environmental pressures are forcing manufacturers of devices and assemblies to squeeze design margins. Users push to gain efficiencies through higher utilisation of assemblies. These pressures are making it increasingly essential to have the capabilities of assemblies well defined and to know in detail the characteristics of the application. The move toward closer links with the installation rules, particularly in respect of rating of circuits, is a positive step towards closely matching the assembly to the application. In addition, it is imperative that every assembly is fully verified in accordance with the standard to ensure it meets its declared capability and the needs of the application.

Clearly the changes are diverse, but all are necessary to ensure the assembly required for a specific application is the assembly provided.

Figure 1

Example of a modern LV switchboard assembly – Schneider Electric Prisma P

Introduction:

After nine years and many hours of discussion within committee, Edition 3 of IEC 61439-1 (Low-voltage switchgear and controlgear assemblies: General rules) and IEC 61439-2, (Low-voltage switch gear and controlgear assemblies: Power switchgear and controlgear assemblies) have finally been published. Soon these documents will become British Standards.

The new editions include many updates which are intended to bring the standards in line with current market needs, closer alignment with electrical installation rules, recognise evolving technologies, ease where appropriate design verification, or clarify areas that have led to confusion in the past. As a result, there are fundamental changes that will significantly affect all parties with an interest in assemblies from specifiers, users, manufacturers and certification bodies, to clarifications that are little more than good practice.

The purpose of this paper is to highlight the main changes in the new editions of the standards and give the reader a little insight into the logic behind the changes. However, this paper is not a substitute for reading the standard.

Reminder of the basis of the standards:

The relationship between IEC 61439-1 and IEC 61439-2 has not changed. IEC 61439-1 remains a general rules document; a collection of common clauses applicable to most assemblies. It is intended to harmonise as far as practical requirements for all types of assemblies. No assembly should be deemed to conform to or be certified in accordance with this document. IEC 61439-2 is the standard for power switchgear and controlgear assemblies. It invokes virtually all of IEC 61439-1 and adds to it as appropriate for power switchgear and controlgear assemblies.

Market evolution:

Applications and opportunities continue to evolve in all areas of business, with low-voltage assemblies being no exception. **The need for greener energy, enhanced safety, energy efficiency, etc. have all influenced the new editions of the standards.** Increasingly, low-voltage assemblies are at the heart of an energy management system. Many now include the automation and intelligence necessary to optimise energy use throughout an installation.

Assemblies for photovoltaic installations (PVA assemblies)

With the move towards renewable energy there continues to be a proliferation in photovoltaic generation, in some instances at voltages up to 1500V DC. This has prompted the inclusion of an Annex in IEC 61439-2 to cover the requirements for assemblies for photovoltaic applications.

The Annex, whilst informative and therefore not mandatory in this edition of IEC 61439-2, considers previous experiences (e.g. fires in combiner boxes) and recognises that the application is more onerous than that of typical assembly. Additional verifications are included to ensure these assemblies are fit for purpose. These include; (i) temperature rise tests with all circuits operating at rated current, simultaneously, in the maximum ambient temperature; if the assembly is likely to be subject to direct sun, the tests are carried out with simulated solar irradiance; (ii) thermal cycling tests to confirm the ability of an assembly to function correctly when there are rapid changes in temperature; and (iii) climatic tests to confirm the assembly is suitable for operation in a hot, damp climate.

Figure 2

Assembly under test conditions with simulated solar effects

Such verifications are not easy to conduct, specialist laboratory equipment is required, but they are considered essential by international experts to prove assemblies will continue to perform correctly over their anticipated life.

Internal arc fault performance for enhanced safety

Historically, many markets, including the UK, have taken the view that the possibility of an arcing fault within a good quality and correctly operated, low-voltage assembly is a very remote possibility, a philosophy of prevention rather than cure.

Some industries and markets now wish to reduce the very small risk of an issue due to an arcing fault even further. They are asking for arc fault tested assemblies and/or the inclusion of arc fault sensing, and in some instances arc quenching means.

For the first time IEC 61439-2 acknowledges this emerging market need and refers to several documents dealing with this subject, namely; (i) IEC 61439-0: Guidance to specifying assemblies; (ii) IEC 61641: Guide for testing under conditions of arcing due to internal fault; and (iii) IEC TS 63107: Integration of internal arc fault mitigation systems in power switchgear and controlgear assemblies (PSC – Assemblies) according to IEC 61439-2.

The latter document is new and provides details on the testing necessary to confirm correct incorporation of the arc fault mitigation systems into assemblies. It also obliges manufactures to identify areas within the assembly where the arc fault detection system will not effectively detect an arcing fault.

DC assemblies

In the past DC has been rarely used, except in some specialist applications. It can lead to corrosions issues, it is more difficult to switch than AC and historically there was only a limited number of DC circuit breakers and switches available. This is now changing, more power generation is DC, (photovoltaic, wind), battery storage is more prominent, a wide range of DC devices are now available, and DC distribution is finding favour in some instances.

In anticipation of a demand for more DC assemblies, IEC 61439-1 & 2 has a greater focus on DC. The standards now:

- **Recognise AC short time current withstand test** (not making and breaking tests) can be used as verification for DC short time current withstand capability.
- **Make frequent reference** to AC rms or mean value of DC.
- **Provide clarity** on when AC and DC dielectric tests should be used.
- Suggest a DC peak factor of 1.42 when conducting DC short circuit tests.

How far the technical and economic benefits will take this trend remains to be seen.

Technical changes:

Significant technical changes have been introduced in the standard that will affect the way in which assemblies are specified and used. **It is crucial these changes are understood** if misunderstandings between the manufacturer and specifier are to be avoided.

Group rated current

In Edition 2 of IEC 61439 a manufacturer is obliged to declare a rated current for each circuit within the assembly and a rated diversity factor for a section within an assembly, or, for the assembly as a whole. This has led to unease and controversy in some markets where manufacturer's have carried out a single temperature rise test with a relatively low current on each circuit, and then claimed the assembly has a unit diversity factor, but without openly declaring the low-test current in each circuit of the assembly as the rated current of each circuit of the assembly.

To overcome these issues with Edition 2 in the market and bring the assembly standard closer to the electrical installation rules, the IEC 60364 series, a new characteristic has been introduced, the 'group rated current of a main circuit'.

The introduction of this new characteristic, the 'group rated current of a main circuit' is the most significant change within IEC 61439-1. It is defined as;

'Rated current which a main circuit can carry considering the mutual thermal influences of the other circuits that are simultaneously loaded in the same section of the assembly'

Further amplification of this definition within the standard confirms that a minimum of one other circuit within the section must be loaded, and that the specific loading arrangements of the section is defined by the manufacturer.

This provides more flexibility for rating circuits than the previous need to specify the rated current for each type of a circuit and the diversity factor for a section or a complete assembly. With the new characteristic, a specific device, e.g. 630A moulded case circuit breaker, can be incorporated in a circuit within an assembly and have a multitude of group rated currents depending upon the loading of the adjacent circuits, heat transfer effects to or from the associated busbar and it's relative vertical position (top, bottom, etc.) within the section.

The characteristic 'rated current of a circuit of an assembly' has been retained in Edition 3 of the standard. It is determined in the same way as in Edition 2 and provides the limit for continuous loading on an individual circuit within an assembly. The characteristic rated diversity factor has also been kept, but instead of it being an arbitrary value usually verified by test, it is now defined as the group rated current of the circuit divided by the rated current of the circuit. Other than being a link to the past it serves little purpose.

Rated currents of circuits

For a given circuit within an assembly there can be three current ratings to be considered:

- **The rated current of the device.** This is the rated current of the device established in accordance with its product standard e.g. a moulded case circuit breaker in accordance with IEC 60947-2. Such ratings are established under defined conditions, usually in free air, with specific test connections.
- **The rated current of a circuit of an assembly,** the current the circuit within the assembly can carry when it is the only circuit loaded within the section of the assembly or the complete assembly.
- **The group rated current** of a circuit of an assembly.

Within most assemblies, for a given circuit, the rated current of the device will be the highest, the rated current of the circuit within the assembly will be lower and the group rated current the lowest of the three ratings.

In the absence of any other information, IEC 61439-2 suggests, but does not mandate, manufacturers establish group rated currents based on the rated current of the device multiplied by the assumed loading factor given in the table below.

Table 1
These are the same values of assumed loading as given in Edition 2 of IEC 61439-2 and the values frequently used as the diversity factor for the assembly.

Type of load	Assumed loading factor
Distribution - 2 and 3 circuits	0,9
Distribution - 4 and 5 circuits	0,8
Distribution - 6 and 9 circuits	0,7
Distribution - 10 or more circuits	0,6
Electric actuator	0,2
Motors ≤ 100 kW	0,8
Motors < 100 kW	1,0

Links to the installation rules (IEC 60364 series)

Electrical installation designers usually establish a design current for each circuit within an installation. **Essentially this is the continuous full load current of the circuit.**

IEC 61439-1 states that the design current of the circuit within the installation should not exceed the group rated current of the corresponding circuit within the assembly. The only exception to this is when the loading characteristics of circuits are well known and permit an increase. If one circuit within a section is heavily loaded and all adjacent circuits lightly, intermittently, or not loaded, for example, duty and stand-by circuits, the combined thermal effects may permit the load on a circuit within an assembly to be increased, but the design current of the circuit within the installation should never exceed the rated current of the circuit within the assembly.

Assuming the rated current of a circuit within an assembly has been determined and that it is appropriate, this ability to increase the loading of a circuit within an assembly above its group rated current provides an opportunity for improved utilisation of assemblies and cost savings.

With the forgoing in mind, the electrical installation designer is encouraged in the standard to include the design current of each circuit within the installation in their specification for the assembly. **This enables the assembly manufacturer to put forward the most cost-effective arrangement,** and at the same time, take full responsibility for providing suitably rated circuits within the assembly.

Current ratings

When considering current ratings of circuits associated with an assembly it is essential to note:

- According to the standard, if a specifier does not stipulate which current rating they are specifying, rated current of the device, rated current of the circuit of the assembly, group rated current of the circuit of the assembly or the design current in accordance with the electrical installation rules, **the assembly manufacturer will assume it is the rated current of the device.**
- The group rated current of a circuit cannot be specified in amperes alone. **The assembly manufacture must define the loading of the adjacent circuits for which the group rated current applies.**

Group rated currents of circuits within assemblies offer opportunity to optimise assembly design and increase utilisation of the assembly. Matching assembly performance to the application through closer association with the installation rules is a major opportunity to be environmentally friendly and optimise use of scarce resources. However, with every opportunity there are risks and responsibilities. Great care is required in the specification and application of assemblies if misunderstanding and issues are to be avoided.

Assembly environment

Most devices that are to be incorporated in assemblies are suitable for use in a specific environment as defined by a pollution degree, namely, pollution degree 1, 2, 3 or 4. Power switchgear and control gear assemblies are usually required to be suitable for installation in a pollution degree 3 environment, whilst many of the components to be installed in the assembly are only suitable for a pollution degree 2 environment.

Previously when the assembly standard was considering the pollution degree applicable to the assembly environment, it was not clear if the environment being considered was that inside the assembly, or the place in which it was installed. **In Edition 3 of IEC 61439-1 this has been clarified.**

The environment in which the assembly is to be installed is defined as the Macro environment and the environment inside the assembly is the Micro environment. Furthermore, the standard makes it clear that with a suitable enclosure, and possibly some form of air management system, e.g. use of dust filters or anti-condensation heaters, the environment inside the assembly can be less polluted than that outside; thereby facilitating the use of a wider range of components inside the assembly, without concern.

Insulating materials

Insulating materials are widely used in assemblies. Most are part of devices with their requirements being dealt with in the associated product standard. However, some insulated parts, such as busbar support and barriers, that are specific to the assembly, **need to have characteristics suitable for their application.**

Some characteristics have always been proven, but this has been by design verification with the assembly in new condition. Aging, and particularly aging of insulation, has not been effectively considered.

All hydrocarbon-based insulation ages as a function of temperature and time. At low-voltage the most likely form of aging is a degradation of mechanical properties, but the temperature and rate at which this occurs varies markedly between insulating materials. For example, some grades of acetal will have a life of 5 years at a constant temperature of 60ºC, whereas some grades of glass reinforced polyester have a life of 40 years at a constant 130ºC.

Edition 3 of IEC 61439-1 now insists consideration is given to the life of insulation. Insulating materials must have a life at its operating temperature within the assembly at least equal to the design life of the assembly. Fortunately, this characteristic is usually available from the material manufacturer or publicly available data bases such as UL746B.

Further temperature rise verification by analysis

Since its inception the standard has always recognised that it's impractical to type test every conceivable arrangement of assembly. **Where it is safe to do so, alternatives to verification by test are permitted.** In line with this philosophy, further areas of temperature rise verification without testing the specific arrangement of assembly have been included.

Active cooling of assemblies

Earlier editions of the standard did not mention active cooling of assemblies; leaving the assembly manufacturer no option, other than test, as the means of temperature rise verification. **Edition 3 of IEC 61439-2 now includes verification of assemblies with active cooling by calculation providing the rating of the assembly does not exceeding 1600A.**

The means of cooling is not prescribed in the standard, it can be by fans, air conditioning units, heat exchangers, etc. The validity of the result with the calculation defined is very dependent on the accuracy of the cooling equipment manufacturer data, but for designers seeking strict compliance with the assembly standard, it will be very useful, particularly as more static devices are incorporated where forced cooling cannot be avoided.

Circuits within higher rated assemblies

Concerns around induced heating of steelwork, current displacement within conductors, etc. have previously limited temperature rise by calculation to assemblies with a rated current not exceeding 1600A. Since most variations within assemblies occur in circuits with a relatively low current rating this restriction has proved problematic. If a change was made to a circuit, or a new circuit created, with a low current rating in an assembly with a current rating in excess of 1600A, the only option was temperature rise verification by test.

To ease this issue, whilst ensuring temperature rise conformance, a method of temperature rise verification using a combination of comparison to a reference design and calculation has been introduced for circuits with a rating not exceeding 1600A, in an assembly of any rating.

To use this method, the power loss of the components to be included in the new circuit must be known and a reference design for the assembly must be available. The current ratings of the reference design assembly must be at least equal to the rating of the assembly in which the new circuit is to be installed. In addition, the power loss of the busbars in the reference design must has been measured during temperature rise tests on the reference design.

As it has not been a requirement to measure the power loss of busbar systems during temperature rise testing, the lack of this information may restrict the use of this method until reference designs including this additional information are available.

Clarifications:

As with most standards covering complex equipment such as assemblies, previous editions of the standard have included areas which have not been comprehensively addressed or that have led to debate between interested parties. **Edition 3 of the standard resolves a number of these grey areas.**

Classes of assemblies

Edition 3 of the standard has adopted the protection system used by other standards and introduced Class I and Class II assemblies.

Class I assemblies are required for most applications within the UK, since most electrical installations have protective circuit for fault protection that requires an earth fault current to return to source via the assembly. Usually, Class I assemblies are metal enclosed, but they can be housed in insulated enclosures that includes a protective (earth) circuit.

Class II assemblies are typically used in IT installation where there is no protective circuit. Usually they are housed in enclosures made of double or reinforced insulation, with special attention being required for anything that penetrates the enclosure. Whilst the standard only considers Class II assemblies with protection by double or reinforced insulation, other methods are available when suitable precautions are employed.

Figure 3

Example of a Class II assembly

Incorporation of devices

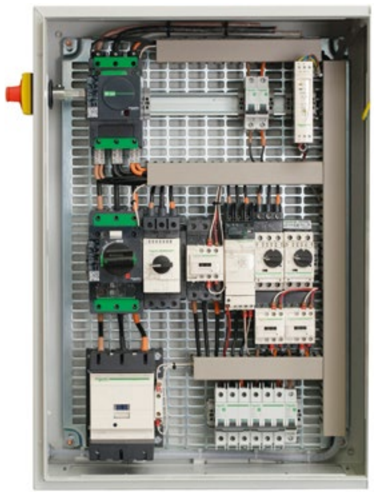
Increasingly in some circles the need to repeat device verifications as part of assembly verification is debated. **Edition 3 of the standard makes clear the function of the different verifications.** All devices should be fully verified/type tested in accordance with their product standard to ensure they are capable of their intended performance as a device.

Verifications in accordance with the assembly standard are intended to confirm the devices have been incorporated in such a way that the devices performance and interaction with other devices within the assembly, does not impair the performance of the device to an extent where it is unable to perform its intended duty within the assembly.

If a device, for example, a variable speed drive, is incorporated into an assembly, there is no need to repeat all the variable speed drive tests. The drive should be incorporated using all the installation guidance from the variable speed drive manufacturer and then its incorporation verified in accordance with the assembly standard. Responsibility for the correct incorporation and functioning of the device within the assembly rests with the assembly designer.

Figure 4

Example of an assembly containing variable speed drives



Conductors passing through ferromagnetic materials

Despite it being a very easy to prove by test, over the years there has been much debate and concern as to when it is permissible to pass a single conductor through a hole in a ferromagnetic material, typically steel. As the answer is dependent upon the material, it's thickness and the amount of material surrounding the hole, there is no simple arbitrary answer that fits all situations.

However, to provide some clarity, the standard has now confirmed that assuming the current carried by the conductor does not exceed 200A, there is no issue. **If the conductor is carrying in excess of 200A a test should be performed to ensure satisfactory performance.**

Forms of separation

Forms of separation remains a matter for agreement between user and manufacturer, but there is now a requirement that when the compartment is opened via the usual access route, all exposed live conductors must be shrouded in accordance with IPXXB of IEC 60529. No longer, as is still practiced in some areas of the world, is it acceptable to have exposed live conductors between the busbars and the isolating device, once the compartment has been opened.

Essentially this is IEC catching up with UK good practice. All other aspects of Forms of Separation remains' essentially unchanged; the use of a device's integral enclosure as the means of separation continues to be acceptable.

Future

Out of necessity, the IEC 61439 series will continue to evolve. The application for assemblies is changing rapidly. Instead of its traditional role of being a dumb piece of equipment, to allow isolation of a circuit and to take action in the event of a fault, assemblies are fast becoming the brain and master of the low-voltage network. IEC TR 63196 places the assembly at the heart of a fully automated energy efficient network.

The need for total automation coupled with the need for very few, if any, interruptions in electrical supplies leads to requirements for, defined reliability, predictive rather than routine maintenance and when necessary, maintenance with very limited isolation. **In turn this, and the general quest for ever more safety, brings a need for added safety features within assemblies.**

To address these emerging needs and other subjects as required by the market, IEC will continue to update standards and develop new documents. The IEC 61439 series will continue to evolve with consideration given to new topics such as aluminium conductors. New document associated with low-voltage assemblies continue to be developed. IEC TR 63196 on energy efficiency has just been published and a further document, IEC TS 63058 on environmental aspects is about to be published. In addition, and in support of the evolving market, a document on 'intelligent assemblies' that will ensure smart devices are correctly incorporated in assemblies, is proposed.

Figure 5

Example of a modern switchboard design incorporating communications and metering

Conclusion

It has taken a long time to reach international consensus on the 3rd Editions of IEC 61439-1 and IEC 61439-2. The new editions include many changes, some are very significant and will affect the way in which assemblies are specified, manufactured and used, while others will have minimal effect on previous good practice.

All the changes are either a recognition of the needs of assemblies in the present and future market, technical advances, further options in design verification or clarifications. These changes have been made with simple objectives in mind; ensuring assemblies are fit for purpose and there is a clear understanding between specifier and manufacturer.

As manufacturers of devices and assemblies squeeze design margins, and users push to gain efficiencies through higher utilisation of assemblies, it is increasingly essential to know the capabilities of assemblies and the characteristics of the application. **To ensure the assembly characteristics are established and that it fulfils its declared capability it is essential that every assembly is verified in accordance with the standard.**

The move toward closer links with the electrical installation rules, particularly in respect of rating of circuits, is a positive step in matching the assembly to the application. When the electrical installation rules and the assembly standard are truly applied, the assembly provided will efficiently and effectively meet the needs of the application