How to specify the 'right' Low Voltage Motor Control Centre

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Abstract - How to use the Low-voltage switchgear and controlgear "Guidance to specifying assemblies" (IEC/TR 61439-0) to specify a Low Voltage (LV) Motor Control Centre with the correct features for his particular application(s).

The IEC standard covering LV switchgear does not focus on the specification of the job it covers the technical aspects of the assembly.

For different applications, different solutions can be adopted and the standard has the flexibility to accommodate these differences. This flexibility, however, comes at a price since it means the specifier of the switchgear has to provide the manufacturer with substantial amounts of information if the manufacturer is going to offer the "right" switchgear for the application.

Most specifiers are familiar with "headline" values such as short circuit withstand currents and times. What they may be less familiar with are the implications for both cost and size of the switchboard for what might appear to be minor requests. Examples of this are diversity factor, ingress protection, form of separationand ambient temperature.

Therefore before starting to specify a board it is sensible for users to first be clear what features they require and why. The most common key functional requirements of continuous process industry users are very high reliability and the ability to work on spare or faulty motor starters safely while the remaining circuits remain energized. High levels of safety (by design) in terms not only of degree of protection from direct contact but also the ability to withstand an internal arc are often seen as mandatory.

The following text describes the features that need to be specified and explains the implications when the specification exceeds values assumed as in the IEC standard.

Index Terms — LV Motor Control Centre.

I. INTRODUCTION

The IEC 61439 series of standards comprises assemblies for a wide variety of use. In the IEC 61439-1 the general rules for low voltage switchgear and controlgear are defined. In the parts 2 up to and including 6 application specific assembly specifications have been or are currently being developed.

The IEC 61439 series consist of:

IEC 61439-1 : Low-voltage switchgear and controlgear assemblies – Part 1 :, General Rules.

IEC 61439-2 : Low-voltage switchgear and controlgear assemblies - Part 2: Power switchgear and controlgear (for authorized persons).

IEC 61439-3 : Low-voltage switchgear and controlgear assemblies - Part 3: Distribution boards intended to be operated by ordinary person.

IEC 61439-4 : Low-voltage switchgear and controlgear assemblies - Part 4: Assemblies for constructions sites.

IEC 61439-5 : Low-voltage switchgear and controlgear assemblies - Part 5: Assemblies for power distribution in public networks.

IEC 61439-6 : Low-voltage switchgear and controlgear assemblies - Part 6: Busbar trunking systems (busways).

IEC 61439-7 : Low-voltage switchgear and controlgear assemblies - Part 7: Assemblies for specific installations at public sites such as marinas, camping sites, market squares and similar applications and for charging stations for Electrical Vehicles

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The technical report IEC/TR 61439-0 is the guidance to specifying low-voltage switchgear and controlgear assemblies.

At the time of writing this paper the IEC/TR 61439-0 still has release edition 1.0

Edition 2.0 is expected to be published in April 2013

This edition 2.0 will have no changes in content. It will have editorials to fulfill alignment with Edition 2.0 of IEC 61439 part 1 and 2.

The technical report identifies, from a user's perspective, those functions and characteristics that should be defined when specifying assemblies. It provides:

- An explanation of the Assembly characteristics and options within the IEC 61439 series.
- A guidance on how to select the appropriate option and to define characteristics so as to meet specific application needs, using a functional approach
- An assistance is the specification of assemblies.

II. ASSEMBLY CHARACTERISTICS

A. Electrical System

The electrical system includes all of the elements of the electrical network within which the assembly is intended to operate.

The characteristics (capabilities) of the assembly should be equal to or exceeding the needs of the application.

The user should provide next information necessary to define the requirements for the assembly:

1) Earthing System:
The means of earthing a low voltage network, when, how and where, differs from application to application.
The standard configurations of earthing systems are TT, TN-C, TN-C-S, IT, TN-S.
Specific systems require and/or permit different solutions.

2) Nominal Voltage:
When provided with the nominal voltage, the manufacturer will determine the appropriate values for other voltages including:
    - The rated operational voltage Ue
    - The rated insulation voltage Ui

3) Transient overvoltages:
The overvoltage category (OVC) options are:
Category I, II, III or IV

. As per IEC 60664 overvoltage category III is applicable for electrical installations.

With the information on OVC and nominal voltage and earthing system, the manufacturer determines the rated impulse withstand voltage Uimp.

The rated impulse withstand voltage (Uimp) defines the transient overvoltage to be withstood. The specification of Uimp is not only important for the dimensions of the clearance distances. It shall be taken into account too for selecting the components and apparatus installed in the switchgear, as these have their own specification for Uimp.

4) Temporary overvoltages:

The ability to withstand temporary overvoltages is verified in the standard with the power frequency withstand test. The voltage level is related to the specification of the rated insulation voltage Ui. The rated insulation voltage (Ui) defines the level of temporary overvoltage to be withstood. The specification of Ui is important for the dimensions of the creepage distances. It shall be noted that the components and apparatus installed in the switchgear shall comply with this specification too.

The user should specify the conditions to be met, if unusual voltage transients or temporary overvoltages are anticipated.

5) Rated frequency:
Standard frequencies are 50 Hz and 60 Hz
Manufacturer uses plus/minus 2 % of the rated frequency as suitable.

6) Additional on site testing requirements:
Wiring, operational performance and function.
The routine verification is intended to detect faults in material and workmanship. It is made on each assembly.
The IEC 60364-6 defines on-site verification to check the correct integration of the assembly into the electrical system.

B. Short-circuit withstand capability

Short-circuit currents and short-circuit current breaking may cause:

- Extremely high forces between conductors
- Very high temperature rise in a very short time
- Air ionization due to arc breaking (lower air insulation)
- Overpressure due to arc breaking (high forces applied to the enclosure)

Information necessary to define the requirements for the assembly:

1. Prospective short-circuit current at supply terminals Icp (kA)
This current would flow if the supply conductors to the assembly were short-circuited with negligible impedance at the supply terminals of the assembly.
With this specification the next ratings will be defined:
    - Rated peak withstand current. (Ipk)
    - Rated short-time withstand current. (Icw)
    - Rated conditional short-circuit current of an assembly. (Icc)
2. Prospective short-circuit current in the neutral.
User should specify if the neutral short circuit current exceeds 60% of the three-phase short-circuit current.
3. Prospective short-circuit current in the protective circuit.
User should specify if this short-circuit current differs from the three-phase short-circuit current.
4. Short-circuit protective device (SCPD)
User may nominate that the SCPD is to be included in the assembly, or that it is to be external to the assembly.
5. Co-ordination of short-circuit protective devices.
If the operating conditions require maximum continuity of supply, the settings or selection of the short-circuit protective devices within the assembly will, where possible, be so graded that a short-circuit occurring in any outgoing branch circuit is cleared by the switching device installed in the faulted branch circuit without affecting the other outgoing branch circuits, thus providing selectivity of the protective system. The manufacturer should provide information how to accomplish this situation.
6. Data associated with loads likely to contribute to the short-circuit current.

C. Protection of persons against electrical shock

C1) Basic protection (against direct contact)
- Provided by insulating material
- Barriers or enclosures

C2) Fault protection (against indirect contact)
Protection by:
- Automatic disconnection of the supply
- Electrical separation
- Total insulation

D. *Installation environment*

The ambient conditions at the place of installation, detailing operating conditions such as the presence of liquids, foreign bodies, mechanical impact, UV radiation, corrosive substances, temperature, humidity, pollution, altitude, and EMC.

a) Location type: Indoor or Outdoor.
b) Protection against ingress of solid foreign bodies and ingress of water.
   The degree of protection of an enclosed Assembly will be at least IP2X and, in case of outdoor use, IPX3.
c) External mechanical impact
   Specified IK rating according IEC 62262
d) Resistance to UV radiation
e) Resistance to corrosion
   Severity level A: Indoor equipment and internal parts of outdoor equipment.
   Severity level B: External parts of outdoor equipment
f) Ambient air temperature. Daily average is 35 degrees if not specified different.
g) Maximum relative humidity
   Indoor: 50% at 40 degrees
   Outdoor: 100% at 40 degrees
h) Pollution degree
   Unless otherwise specified assemblies for use in a pollution degree 3 environment will be provided for industrial applications.
i) Altitude
   Assemblies are designed to operate at altitudes less than or equal to 2000m
j) EMC environment
   Environment A: Industrial locations characterized by the existence of one or more of:
   - Industrial, scientific and medical apparatus
   - Heavy inductive or capacitive loads are frequently switched.
   - Currents and associated magnetic fields are high.

   Environment B: Residential, commercial and light-industrial characterized by being supplied directly at low voltage from the public domains network.
k) Special service conditions
   Examples:
   - Causing exceptional condensation.
   - Heavy dust, smoke, corrosive or radioactive particles, vapours or salt.
   - Attack by fungus or small creatures.
   - Heavy vibration or shock and the associated frequency.
   - High energy impacts.
   - Presence of explosive atmosphere.
   - Possibility of exposure to fire.
   - Exceptional overvoltages.
   - Exposure to strong electric or magnetic fields.
   - Exposure to exceptional conducted and radiated disturbances.

E. *Installation method*

1) Assembly type
2) Portability
3) Maximum overall dimensions and weight
4) External conductor type(s)
   - cable
   - busbar trunking system
   - other
5) Direction(s) of external conductors
   - top
   - bottom
   - rear
   - front
   - sides
6) External conductor material
   - copper
   - aluminum
   - other material
7) External phase conductor, cross-sections, and terminations
8) External PE, N, PEN conductors cross-sections, and terminations
9) Special terminal identification requirements

F. *Storage and handling*

1) Maximum dimensions and weights of transport units
2) Methods of transport
3) Environmental conditions during transport, storage and installation
4) Packing details

G. *Operating arrangements*

1) Access to manually operated devices
   - The terminals, excluding terminals for protective conductors, will be situated at least 0,2 m above the base of the assembly.
   - Indicating instruments will be located within a zone between 0,2 m and 2,2 m above the base of the assembly.
   - Operating devices will be located within a zone between 0,2 m and 2 m above the base of the assembly.
   - Actuators for emergency switching devices will be located within a zone between 0,8 m and 1,6 m above the base of the assembly.
2) Isolation of functional units for maintenance or service while adjacent groups of circuits remain energized and in service.
   Such facilities can be provided by the use of measures such as:
   - Sufficient space between the functional unit or group and adjacent functional units or groups.
   - barriers
   - terminal shields
   - compartment for each functional group
   - insertion of additional protective means

H. *Maintenance and upgrade capabilities*

Requirements related to:

1) Requirements related to accessibility for inspection

2) Requirements related to accessibility in service by authorized persons
3) Requirements related to extension under voltage
4) Protection against direct contact with hazardous live internal parts during maintenance or upgrade.
5) Removable functional units and its methods of connection
   Use of three-letter code:
   - First letter to describe the electrical connection of the main incoming supply to the functional unit
   - Second letter to describe the electrical connection of the main outgoing supply from the functional unit
   - Third letter to describe the electrical connection of the auxiliary circuits.

   -F for fixed connections
   -D for disconnectable connections
   -W for withdrawable connections
6) Operating and maintenance gangways within an assembly
7) Internal separation
   To attain:
   - Protection against contact with hazardous parts. The degree of protection shall be at least IP XXB
   - Protection against the passage of solid foreign bodies. The degree of protection shall be at least IP 2X

   This may be achieved by means of partitions or barriers, insulation of live parts or the integral housing of a device.

I. Current carrying capability

1) Rated current I_{nA}
2) Rated current of circuits I_{nC}
3) Rated diversity factor
   If a group of adjacent circuits within an assembly are to operate at rated current at the same time, significant de-rating of components is necessary to ensure there is no overheating.
   In practice not all circuits will carry their rated current continuously and simultaneously.
   The rated diversity factor specifies the average loading conditions for which the assembly (or group of circuits within the assembly) is designed.
4) Ratio of cross-section of the neutral conductor to phase conductors
   - Up to and including 16 mm2 the neutral is 100% of that of the corresponding phases.
   - Above 16 mm2 the neutral is 50% of that of the corresponding phases.

J. Assembly design and routine verification processes

1) Design verification is intended to verify compliance of the design of an assembly with the requirements of the relevant assembly standard in the IEC 61439 series. Usually design verification is carried out on typical arrangements within a standard product range and at the time the product is developed.
2) Routine verification
   This verification is carried out on every assembly that is manufactured to confirm correct and proper functioning.
   Three methods are used:
   A. Verification by testing
   B. Verification by visual inspection
   C. Verification to the component manufacturer's and original manufacturer's instructions.

III. MORE THAN IEC-61439?

End users have different requirements regarding some important MCC parameters.

Below an overview is presented of 4 different end-users:

	Company#1	Company#2	Company#3	Company#4
ambient air temperature	55	35	35 and 55 for 1 hr	25
internal separation	3B	4A	4B	3B
IP rating (indoor)	IP42	IP41	IP4X	IP31
rated diversity factor	1.0	0.9 or 1.0	as per IEC61439 table	not specified
internal arc behavior	IEC/TR 61641 1-7 also when inserting	IEC/TR 61641 1-7	IEC/TR 61641 1-5	not specified

Table 1 : End user specifications

Ambient air temperature (part 0 par. 8.7)

Ambient air temperature requirements depend most often on geographical positions. In areas (e.g. Middle East) MCCs are put into air-conditioned substations but when the aircon fails the MCC needs to continue to do its job (for at least a number of hours to allow for aircon repair).

The impact on MCC design for higher ambient temperatures is such that the MCC will become larger in dimensions and more expensive. Either conservative derating calculations will be used or the vendor will use a verified by testing design at the requested ambient temperature.

Internal separation (part 0, par. 12.8)

Internal separation defines the separation between individually functional units, between functional units and busbars and functional units and outgoing cable terminals.

End users want to be able to do safe insertions / withdrawals of functional units without the danger of touching live parts. In petro-chem projects the minimum requirement is form 3.

End users want to be able to safely install and connect outgoing cables. Outgoing cable terminals need to be individually shielded. In petro-chem projects the minimum is form 3b. Also form 4a and 4b is specified.
Internal separation solutions are very MCC vendor specific. Form 4b of vendor A might be less safe than form 4A of vendor B.

IP ratings (part 0 par. 8.3)

IP ratings define the protection of ingress of insertion of foreign objects. An IP degree above IPXXB means that you can not touch any live parts.

In petro-chem projects end users specify a minimum of IP31 and a maximum of IP42.

The first digit means:

3 : Holes in the enclosure < 2.5 mm

4 : Holes in the enclosure < 1 mm

The second digit means:

1 : Protection against vertically dropping water (eg condensation water)

2 : Protection against dropping water (15 degrees angle, e.g. sprinkler fire extension system).

How higher the IP-rating the less dust may be able to enter the system.

How higher the IP rating of the MCC the less heat is being exchanged by airflow from the MCC.

Higher IP rated MCCs tend to be larger and more expensive.

Higher IP rated MCCs tend to be more reliable because less dust is able to enter the system.

Rated diversity factor (part 0. Par. 13.4)

Rated diversity factor defines the maximum allowable loading of the system. In case of absence of a specific agreement between manufacturer and user reference is made to table 101 of IEC 61439-2.

The IEC 61439-2 edition 1 table 101 suggests assumed loading factors depending of the number of main circuits per panel only. E.g. when more than 10 motor starters are installed into 1 panel it suggest an assumed loading factor of 0.6.

The IEC 61439-2 edition 2 suggests assumed loading factors depending on the type of load. to use a 0.9 fFor motors smaller than 100 kW the assumed loading factor is 0,9.

Type of load	Assumed loading factor
Distribution – 2 and 3 ciircuits	0,9
Distribution – 4 and 5 ciircuits	0,8
Distribution – 6 to 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

Table 2: Values of assumed loading (IEC 61439-2 ed2)

End users in the petro-chem projects specify a rated diversity factor from 1, to 0.9 to none. It shall be noted that the diversity factor is having a major impact on temperature rise levels of a MCC. Assuming the temperature rise inside at different locations the MCC being linear with the heat dissipation and knowing the heat dissipation is lineair with the square root of the current decreasing a rated diversity factor from 1 to 0,9 will decrease the temperature rises by 20% (note: $0,9^2$ = 0,81)

High Diversity Factors will have impact on MCC dimensions and pricing.

Internal Arc behavior (IEC/TR 61641)

Internal Arc behavior is not specified in the IEC 61439. A guideline to Arc testing is given in the IEC/TR 61641. This is not a normative standard, The technical report describes 7 criteria, the more criteria that can be met the more arc-safe a MCC will be.

In most petro-chem projects end-users want to minimize the risk of downtime. They prefer arc prevention measures (eg such as insulated main busbars). However if an arc occurs personal safety is very important. It is a premium when in case of an arc the MCC is also protected (limited damage allowed).

IV. CONCLUSIONS

The standard IEC TR 61439 part 0 offers a checklist for specifying a MCC,

To be able to specify the “right” MCC it is important to know what are the requirements regarding high reliability and the ability to safely perform maintenance activities on starters or feeders when the remaining system is still energized.

Parameters like diversity factor, ingress protection, form factor, ambient temperature and internal arc behavior substantial influence cost and size of the switchgear.

If specifiers have a clear understanding of their needs, then they will be in a much better position to decide if the additional cost, space or other constraints (arising from exceeding the “standard” requirements), are justified.

VI. REFERENCES

[1] IEC 61439 Low-voltage switchgear and controlgear assemblies

[2]

[3]

[4]

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[6]

V. APPENDIX

Example MCC specification using IEC61439-0 table C.1 and table C.2

VI. VITA

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Graduated from the Eindhoven University of Technology in 1988. After several positions in R&D with Holec and manager of the Prof. Ir. Damstra Laboratory he is presently working as technical director for the Entheg Technology Group in The Netherlands. His fields of interest are the assessments of safety and reliability of electrical installations and failure analyses. He is the chairman of the national 17B and 17D committee, dealing with IEC and EN standards for low voltage switchgear and controlgear as well as switchgear and controlgear assemblies and he is a member of several IEC maintenance teams.

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Graduated in 1985 from the HTS Hilversum, the Netherlands with a bachelor degree (ing.) in Electrical Engineering specialization Telecommunications. From 1987 he worked for Rossmark Watertreatment as a process automation engineer and later he managed the process automation department. In 1997 he joint Eaton Electric in the role of application engineer/SCADA specialist. After changing positions to Project Manager and Export Customer Support Manager his current position is Product Manager being responsible for the marketing of LV MCC and Motor Management Systems.