Batteries Division

ZVEI Die Elektroindustrie

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Dimensioning, allocation and design of cell connectors for stationary lead-acid batteries

This leaflet contains information on the design of cell connectors for stationary battery systems.

The use of this leaflet is restricted to lead-acid batteries.

To ensure a durable and secure connection, only components that are fully compatible with the construction-specific connector system may be used. The manufacturer-specific assembly instructions must be observed.

In case of repair, it is recommended to replace removed terminal screws with integrated locking agent by equivalent new terminal screws.

1. Scope

Stationary battery systems consist of single cells or block batteries and are usually installed on racks or in cabinets.

The connectors defined in this information leaflet are used for the electrical connection (interconnection) of single cells or block batteries to stationary lead-acid battery systems.

2. Objective

The purpose is to define the cross section of connectors in order to avoid an inadmissible heating of the connector surface (70°C acc. IEC 60896-22, item 6.10) and/or the exceeding of a maximum voltage drop.

3. Connector types

Connectors are used for the electrical connection of cells or block batteries. According to Fig. 1, it must be distinguished between the following connector types:

- Cell connectors
- Block connectors
- Tier connectors
- Group connectors
- Terminal conductors for the electrical connection of the battery system with the power supply and/or the electrical load.

This information leaflet has been developed by the Industrial Batteries Work Group of the ZVEI – Zentralverband Elektrotechnik- und Elektronikindustrie e. V., Batteries Division

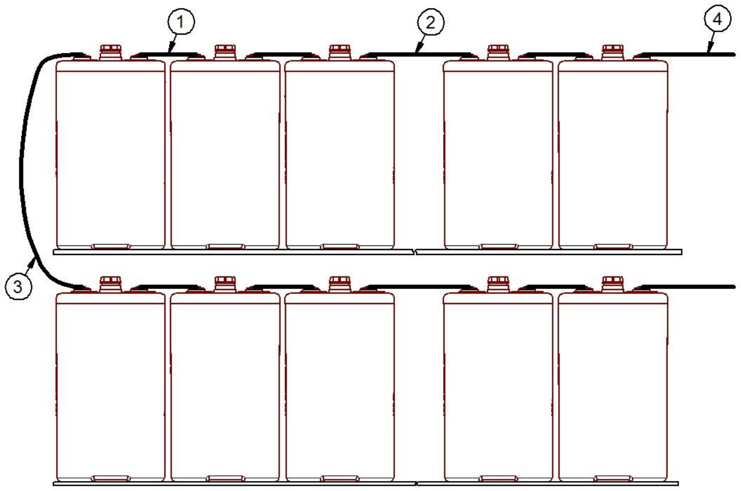

Fig. 1: Connector types

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4. Designs

The following versions of connectors are preferably used:

– flexible, insulated copper cable connectors screwed to battery terminals
– rigid, insulated flat copper connectors screwed to battery terminals.

5. Sizing of cell connectors

Connectors can be designed according to two principles:

1) suitable for all loads occurring under normal conditions of use (standard design)
2) adjusted to the load case intended for the battery system (individual design)

5.1 Standard design

For battery systems which are suitable for universal use and which cover all occurring operating modes of the battery system, the following design criteria have proven themselves in practice:

The cross section of connectors are dimensioned in a way that no inadmissible heating of the connectors occurs when the battery system is discharged with a 15-minute current ($I_{15\ min}$) up to an end-of-discharge voltage of 1.6 volts per cell (discharge with maximum heat generation).

5.2 Individual design

If an individual design is chosen, the operating conditions (amperage, discharge time, possible voltage drop) of the intended application must be known.

Due to the large variety of types, no further recommendation can be given for individual design. The design must be carried out by specialists in a responsible manner.

An increase of loads during the use of this battery may only be carried out if appropriate technical adjustments to the electrical connections are made and documented (e.g. in the instruction manual that should be placed closed to the battery installation).

6. Design of terminal conductors, tier- and group connectors

6.1 Terminal conductors

In general, the maximum current carrying capacity according to point 7 applies.

If the terminal conductors are considered to be extended busbars, the cross section must be designed in order to withstand the current in the event of a short circuit.

Often the maximum permissible voltage drop of the terminal conductor must be considered addtionally; this can lead to larger cross sections.

6.2 Tier connectors

Tier connectors are usually longer than cell connectors. The dimensioning of the cross section is carried out according to point 7.

6.3 Group connectors

Group connectors are usually only slightly longer than cell connectors. The dimensioning of the cross section is therefore

identical with the dimensioning of the cell connectors.
If the length exceeds 3 times the length of the cell connectors, they must be dimensioned according to point 7.

7. Dimensioning of cross section

When considering the general dimensioning of cross sections, the following points should be taken into account.

7.1 Selection according to standard

The selection is made in accordance with DIN VDE 0298-4 " Application of cables and cords in power installations - Part 4, there Tab. 16: "Operating conditions and loading capacity for welding cables" for the operating condition continuous load when laid in air.

The cross section for flat copper connectors can be selected analogous to those of copper cable connectors.

7.2 Alternative selection

As Figure 2 shows, the heating of the connectors depends on the ambient temperature, the current and the installed connector cross section. It is therefore important to ensure that only permissible combinations are used.

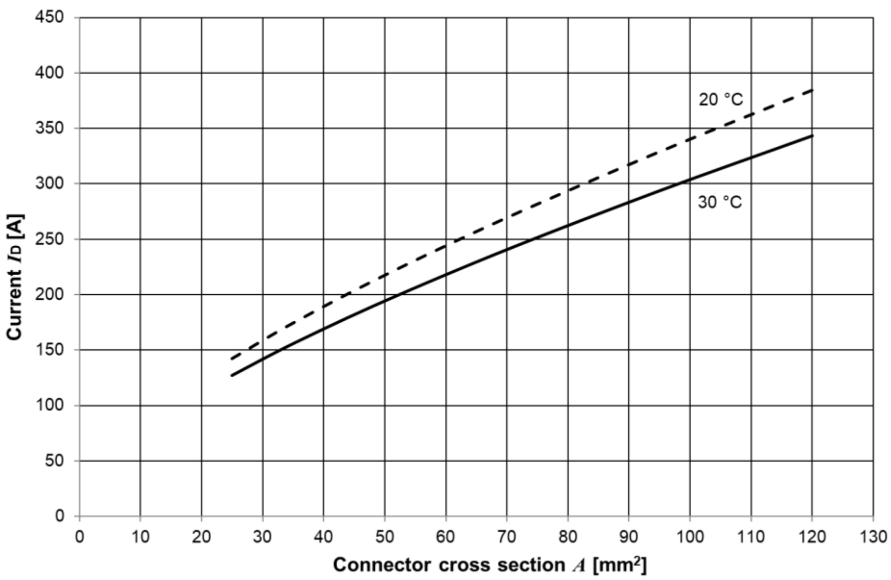

Fig. 2: Current I_D as a function of the connector cross section A at different ambient temperatures.

Alternatively, the maximum permissible current for a selected conductor cross section can be estimated using the following calculation approach:

$$I_D = j \times A \times f_T$$

I_D = continuous current [A]
j = maximum permissible current density for the selected conductor cross section [A/mm²]
A = conductor cross section [mm²]
f_T = conversion factor for deviating ambient temperatures (DIN 298, part 4 / see following Table 1)

Ambient temperature [°C]	conversion factor f_T
10	1,22
15	1,17
20	1,12
25	1,06
30	**1,00**
35	0,94
40	0,87
45	0,79
50	0,71
55	0,61

Table 1: Conversion factors for deviating ambient temperatures.

Calculation for

$$j = \frac{\sqrt{\frac{A \times 4}{\pi}} + 23}{\sqrt{\frac{A \times 4}{\pi}}}$$

When considering the dimensioning of the cell connector cross section , a higher current can usually be applied due to the heat dissipation into the battery cell.

An estimation of the additional possible current can be made using the following formula:

$$I_Z = \sqrt{\frac{c \times m \times \Delta T \times y}{R \times t}} \text{ [A]}$$

I_Z = maximum possible current [A]
c = specific heat copper [381 J kg^{-1} K^{-1}]
m = connector mass [kg]
ΔT = temperature difference between ambient temperature and maximum. permissible connector temperature [K]
R = connector resistance [Ω]
t = 900 [seconds] (15-minute load time)
y = design factor:

- vented cells	0,10
- valve regulated cells (Gel)	0,05
- valve regulated cells (AGM)	0,00

For a temperature difference ΔT of 40 K, I_Z can be determined by using the following simplified formulas:

$$I_Z = \sqrt{\frac{A^2}{900}} \times 28$$ [A] for vented cells

$$I_Z = \sqrt{\frac{A^2}{900}} \times 20$$ [A] for valve regulated cells (Gel)

Therefore, the maximum possible total current for cell connectors is

$$I_G = I_D + I_Z \quad \text{[A]}$$

The following table helps to identify the suitable cable cross section. It is based on the formulas described above and applies to an ambient temperature of 30 °C:

cable cross section	max. current	Continuous current	Additional current			Total current		
A [mm²]	j [A/mm²]	I_D [A]	$I_{Z\,(vented)}$ [A]	$I_{Z\,(closed)}$ [A]	$I_{Z\,(AGM)}$ [A]	$I_{G\,(vented)}$ [A]	$I_{G\,(closed)}$ [A]	$I_{G\,(AGM)}$ [A]
6	9,32	56	6	4	0	62	60	56
10	7,45	74	9	7	0	84	81	74
16	6,10	98	15	11	0	112	108	98
25	5,08	127	23	17	0	150	144	127
35	4,45	156	33	23	0	188	179	156
50	3,88	194	47	33	0	241	227	194
70	3,44	241	65	47	0	306	287	241
95	3,09	294	89	63	0	382	357	294
120	2,86	343	112	80	0	455	423	343
150	2,66	400	140	100	0	540	500	400
185	2,50	462	173	123	0	635	586	462
240	2,32	556	224	160	0	780	716	556
300	2,18	653	280	200	0	933	853	653

*) continuous, additional and total current apply for an ambient temperature of 30°C (f_t = 1,00)

Table 2 – Exemplary calculation of the maximum permissible connector currents for usual cross sections

To be able to determine the required cable cross section, the total current I_G in the table must be selected, which is higher than or corresponds to the $I_{15\,min}$ value.

ZVEI: Die Elektroindustrie

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