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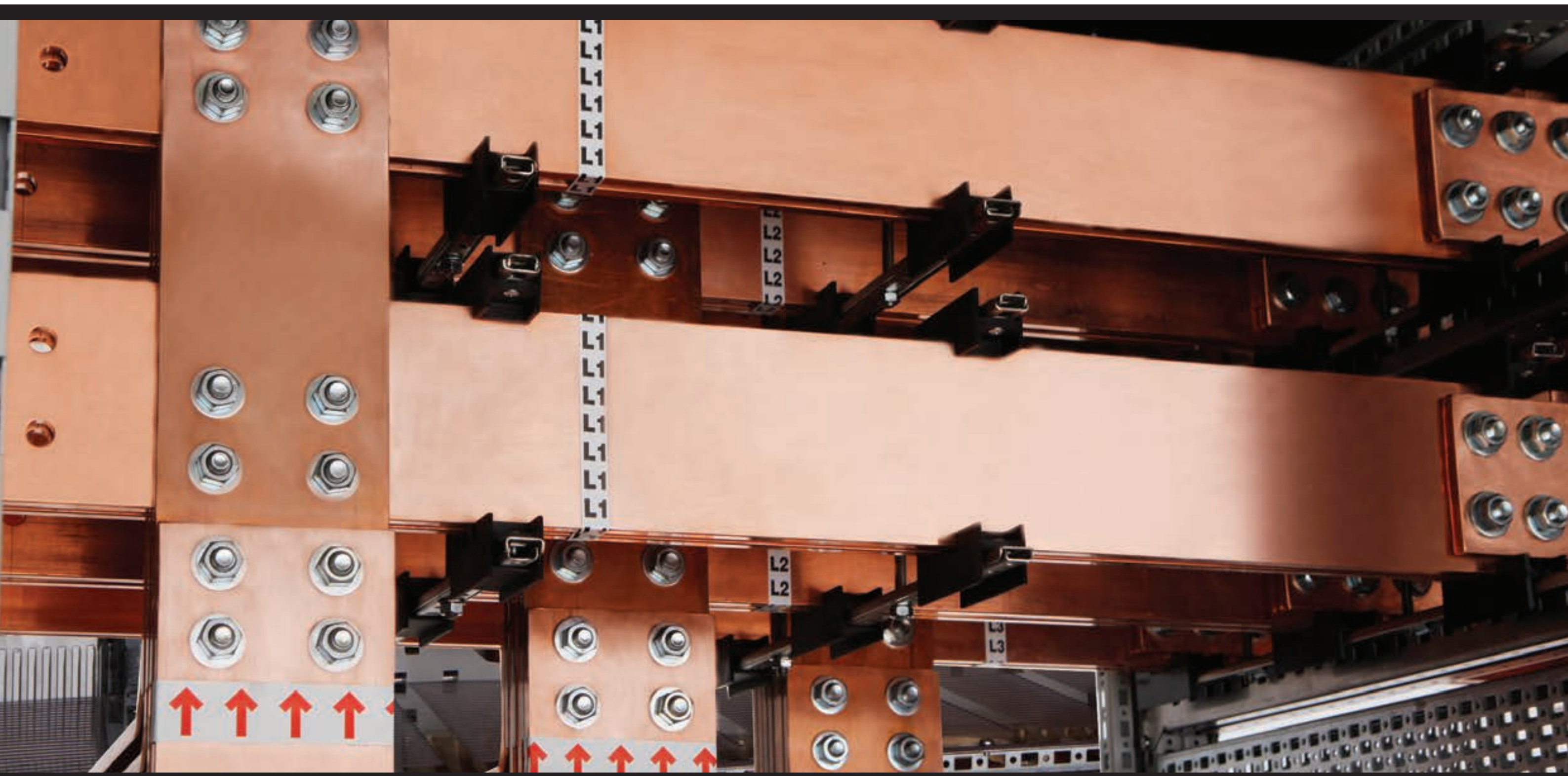

B SERIES

COPPER BUSBAR ASSEMBLY IMPLEMENTATION GUIDE

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CONTENTS

Calculation of copper busbar current carrying capacity

Determination of busbar cross-section suitable for the current

Rectangular sectioned copper busbar current carrying capacity
Calculated as described below according to DIN 43671 (1975).
Charts commonly used in our country
are based on the 1964 version of DIN 43671 standard.

$$I_{busbar}=I_{chart} \times k_1 \times k_2 \times k_3 \times k_4 \times k_5$$

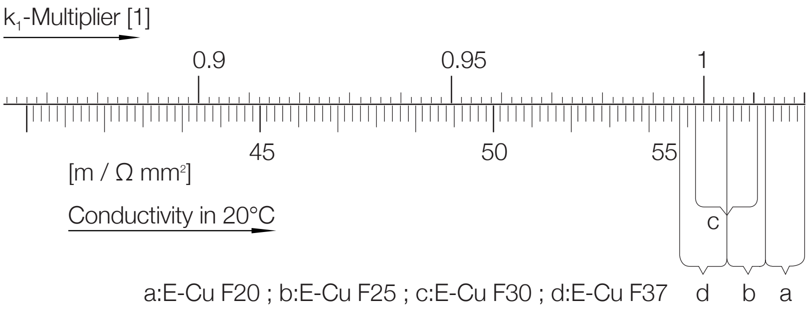
I_{busbar} : Current value of the said busbar [A]
I_{chart} : Current value stated in Chart 1 [A]
k_1,k_2,k_3,k_4,k_5 : Multipliers [1]

Chart 1- Maximum current that E-Cu F30 material copper busbars when they heat up to 65°C according to DIN 43671

Width x Thickness	Cross section	Weight	Alternative current up to 60 Hz							
			Painted				Bare			
			Number of busbars				Number of busbars			
[mm]	[mm^2]	[kg/m]	1	2	3	4	1	2	3	4
12x2	23,5	0,209	123	202	228		108	182	216	
15x2	29,5	0,262	148	240	261		128	212	247	
15x3	44,5	0,396	187	316	381		162	282	361	
20x2	39,5	0,351	189	302	313		162	264	298	
20x3	59,9	0,529	237	394	454		204	348	431	
20x5	99,1	0,882	319	560	728		274	500	690	
20x10	199	1,77	497	924	1320		427	825	1180	
25x3	74,5	0,663	287	470	525		245	412	498	
25x5	124	1,11	384	662	839		327	586	795	
30x3	89,5	0,796	337	544	593		285	476	564	
30x5	149	1,33	447	760	944		379	672	896	
30x10	299	2,66	676	1200	1670		573	1060	1480	
40x3	119	1,06	435	692	725		366	600	690	
40x5	199	1,77	573	952	1140		482	836	1090	
40x10	399	3,55	850	1470	2000	2580	715	1290	1770	2280
50x5	249	2,22	697	1140	1330	2010	583	994	1260	1920
50x10	499	4,44	1020	1720	2320	2950	852	1510	2040	2600
60x5	299	2,66	826	1330	1510	2310	688	1150	1440	2210
60x10	599	5,33	1180	1960	2610	3290	985	1720	2300	2900
80x5	399	3,55	1070	1680	1830	2830	885	1450	1750	2720
80x10	799	7,11	1500	2410	3170	3930	1240	2110	2790	3450
100x5	499	4,44	1300	2010	2150	3300	1080	1730	2050	3190
100x10	999	8,89	1810	2850	3720	4530	1490	2480	3260	3680
120x10	1200	10,7	2110	3280	4270	5130	1740	2860	3740	4500
160x10	1600	14,2	2700	4130	5360	6320	2220	3590	4680	5530
200x10	2000	17,8	3290	4970	6430	7490	2690	4310	5610	6540

Notes: 1) Current values above are values obtained with experiment for 35ºC ambient temperature
2) Busbar distance is the same as busbar thickness for busbar numbers 2, 3 and 4; Distance for twin groups for 4 is 50mm.

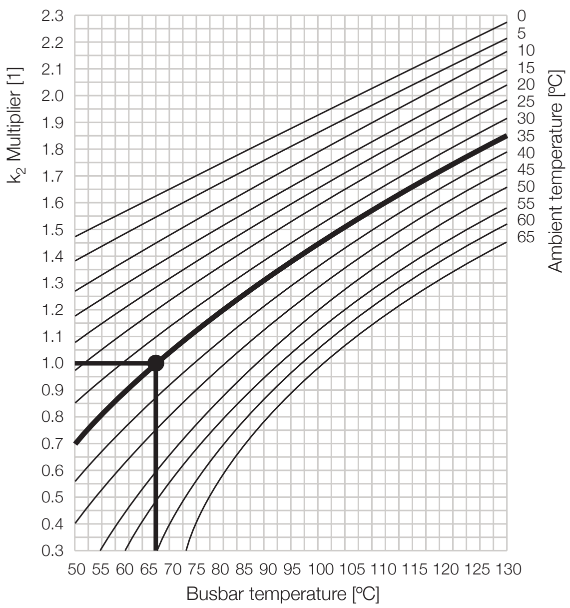
k_1 - Effect of Multiplier / Material



Comments

k_1 Conductivity of the said busbar k1 =1 is used if unknown.

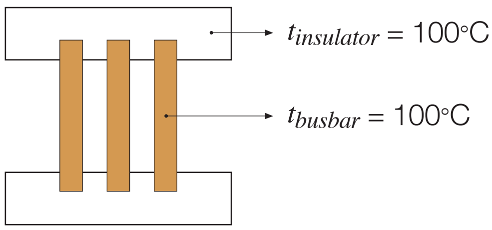
k_2 - Effect of Multiplier / Temperature



Comments

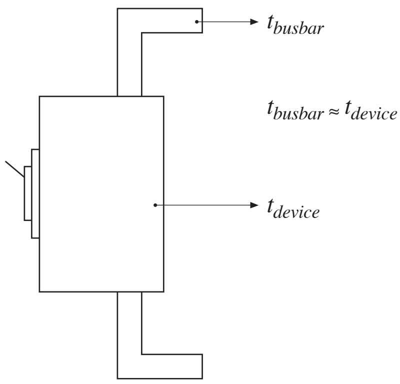
k_2 Heat resistance of equipment in contact with busbars (such as insulators or current transformers) must be considered when determining the temperature level that busbars can reach.

In electricity switch enclosures, busbar temperature must be under 100°C.



Comments

k_2 It must be assumed that switch devices that busbars are connected to will heat under the influence of busbars. Copper is highly heat conductive.



Rated currents of switch devices vary according to the temperature they are in.

Percentages showing the change of rated current of a compact switch according to ambient temperature.

40°C %	100	100	100	100
50°C %	96	92	96	94
55°C %	93	87	94	90
60°C %	91	83	92	87
70°C %	86	73	88	80

k_3 - Effect of order according to Multiplier / Floor

If busbars are arranged horizontally, i.e. parallel to floor or longer than 2m, k3-multiplier is determined according to Chart 2; otherwise k3=1.

Comments	
k_3	Busbars must be arranged vertically in electricity switch enclosures unless otherwise is required.

Chart 2 k3 - Multiplier

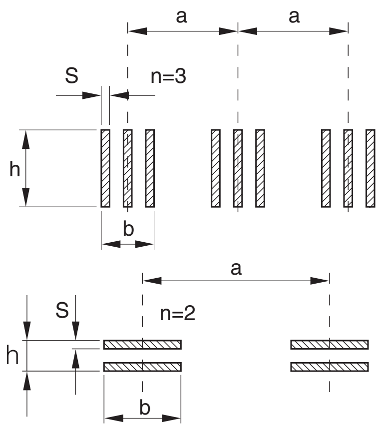
Number of busbars	Busbar Width [mm]	k_3 - Multiplier	
		Painted	Bare
2	50-200	0,85	0,8
3	50-80	0,85	0,8
	100-120	0,8	0,75
4	160	0,75	0,7
	200	0,7	0,65

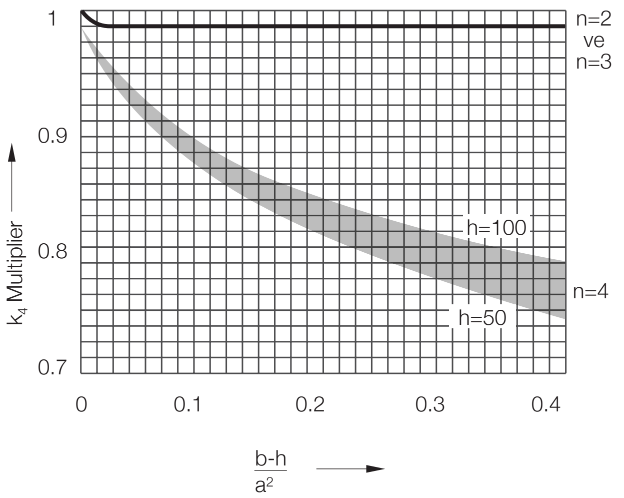
k_4 - Multiplier / Effect of Busbar assembly geometry

This is especially important when distance between phases is small.

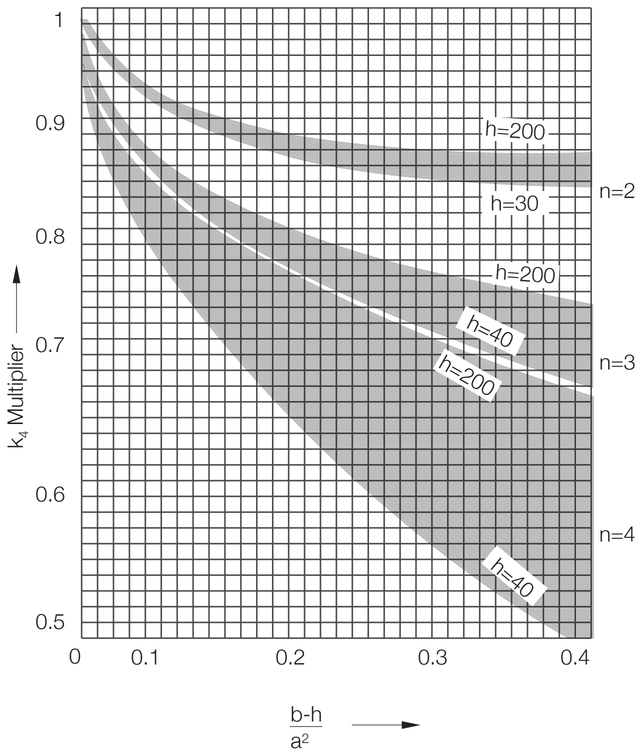
k_4-multiplier is used when there is no outlet in 2m on busbar.

Comments	
k_4	4=1 is generally used for electricity switch enclosures.





k4 multiplier for s=5mm



k4 multiplier for s=10mm

k_5 - Multiplier / Effect of Altitude

Chart 3 k5 – Multiplier

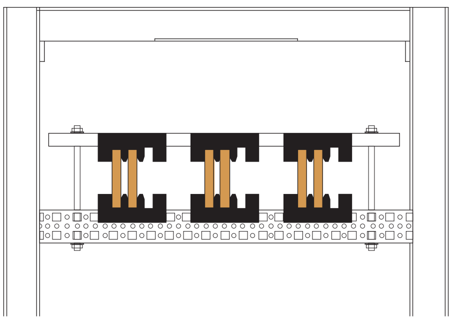
Altitude [mm]	k_5 - Multiplier	
	Internal	External
1000	1	0,98
2000	0,99	0,94
3000	0,96	0,89
4000	0,9	0,83

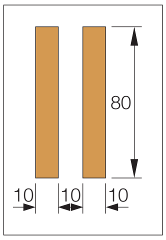
Comment; Ambient temperature is considered as 35°C .

In an average switch enclosure without an additional cooling assembly, heat is distributed 15-20k in height starting from the floor. Outside temperature is considered as 20°C and busbars are considered as located on top of the switch enclosure and ambient temperature for busbars is considered as 35°C.

20°C	+	15K	=	35°C
Ambient temperature of switch enclosure		Temperature increase in switch enclosure		Ambient temperature of busbars

Sample calculation:





Determination of I_{chart} value;

I_{chart}	2x80x10 mm	
painted	2.410 A	%114
bare	2.110 A	%100

2.110 A

Determination of k_1 - Multiplier;

Busbars used in switch enclosures are generally made of E-Cu F25 or E-Cu F30 material.
If no certain information is found on the conductivity of the busbar, k_1=1 can be used.

k_1=1,00

Determination of k_2 - Multiplier;

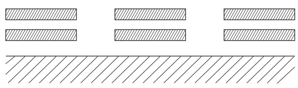
Allowed copper temperature Determination of t_{copper}

t_{copper}	55°C	65°C	75°C	85°C
k_2	0,8	1,0	1,17	1,32
painted	1.928 A	2.410 A	2.820 A	3.181 A
bare	1.688 A	2.110 A	2.469 A	2.785 A

k_2=1,00

Determination of k_3 - Multiplier;

If busbars were arranged side by side,



$k_{3painted}$=0,85

k_{3bare}=0,80

k_3=1,00

Determination of k_4 - Multiplier;

There is no busbar longer than 2m in the sample switch enclosure without any outlet.

k_4=1,00

Determination of k_5 - Multiplier;

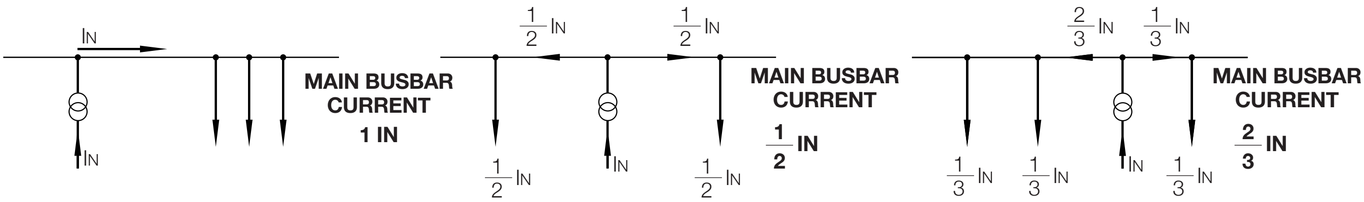
Altitude is lower than 1000m in sample switch assembly.

k_5=1,00

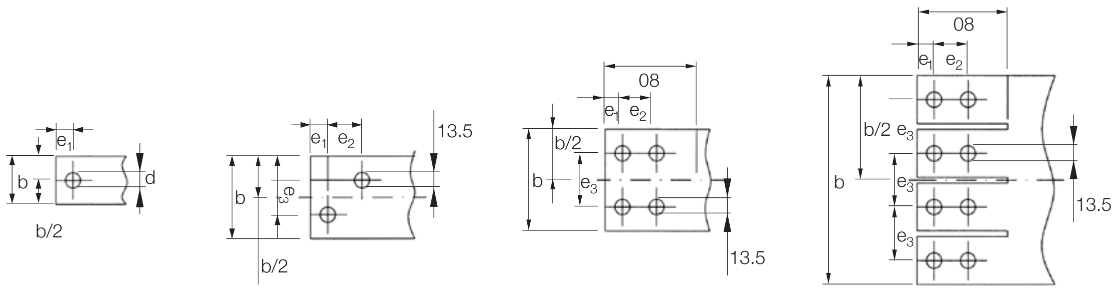
Additional points to consider during copper busbar sizing

Influence of supply point physical location on busbar rated current

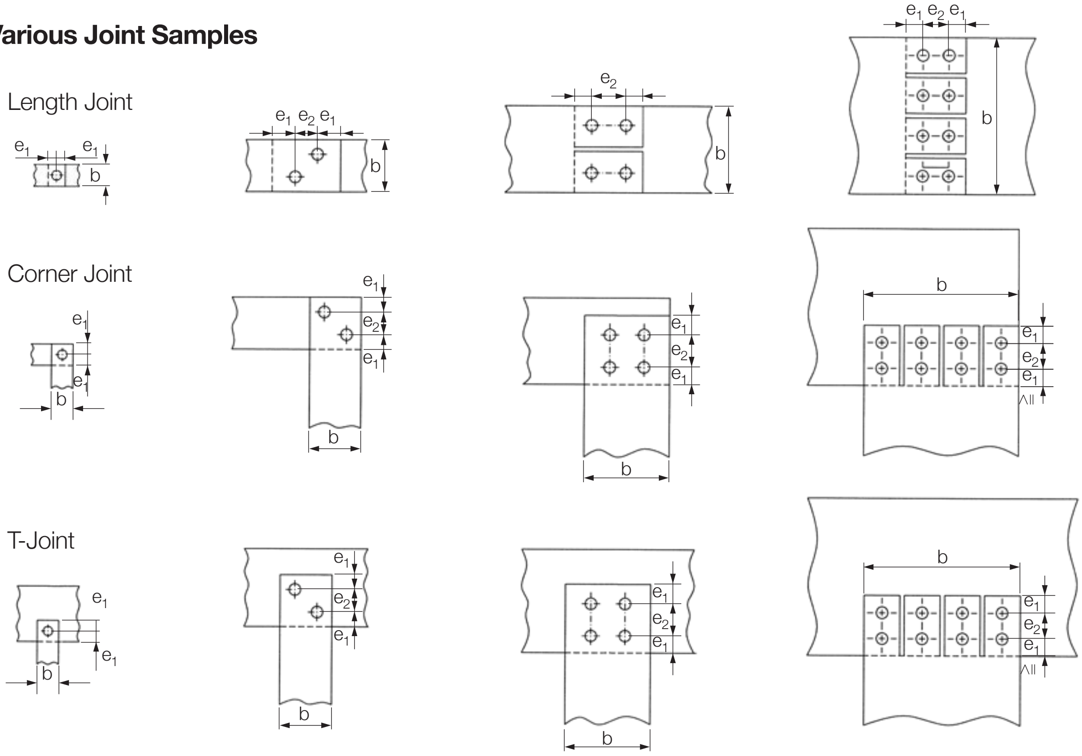
In assemblies consisting of multiple switch enclosures, it is possible to determine suitable supply locations and lower the main busbar rated current by half by supplying from the middle.



Busbar Width



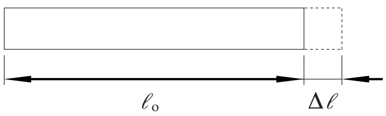
Various Joint Samples



b	d	e1	e2	e3
12	5,5	6		
12	6,6	7,5		
20	9	10		
25	11	12,5		
30	11	15		
40	14	20		
50	14	25		
60	14	17	26	26
80	14	20	40	40
100	14	20	40	50
120	14	20	40	60
160	14	20	40	40
200	14	20	40	50

Expansion of main busbar

Length of busbars increase by expanding due to increase in temperature. This must be taken into account when busbars are supported.



$$\Delta\ell = \ell_0 \times \alpha \times \Delta t$$

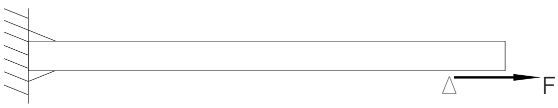
$\Delta\ell$	;	*expansion lengthening*	[m]
ℓ_0	;	*initial length*	[m]
Δt	;	*temperature difference*	[m]
α	;	*thermic expansion coefficient*	[1/K]
		$\alpha_{Cu} = 0{,}000017$	[1/K]

Sample expansion calculation

Expansion amount of 80X10mm cross-section 3m copper busbars used as main busbars of a site that operates in the day but closed at night (t_{day} = 65°C; t_{night} = 15°C) will be calculated.

$\Delta\ell$ = 3000 [mm]x0,000017[1/K]x(65-15)[K]=2,55[mm]

When both ends of the same busbar are tightly supported, forces generated in these support points due to expansion are calculated as shown below.

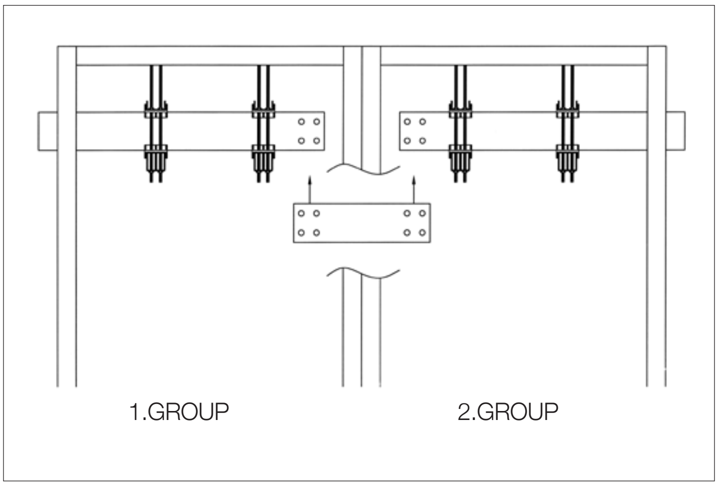


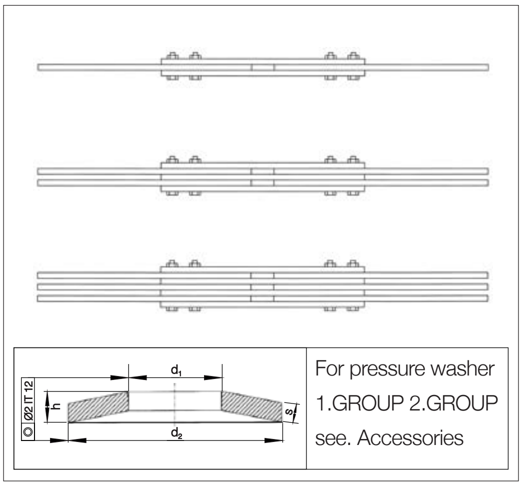
$$F = E \times \alpha \times \Delta t \times A$$

F	;	*force*	[N]
A	;	*cross section*	[mm²]
Δt	;	*temperature difference*	[K]
α	;	*thermic expansion coefficient*	[1/K]
		α_{Cu} 0,000017	[1/K]
E	;	*elasticity module*	[N/mm²]
		$E_{Cu} = 110.000$	[N/mm²]

F = 110.000 [N/mm²]x0,000017[1/K]x(65-15)[K]x800[mm²]=74.800 [N]≈7.480 [kg]

Groups made of multiple electricity switch enclosures are divided into small sections while being transferred from the manufacturing site to the place they will be installed. These sections must not exceed 2-2.5m. Measures must be adopted against the drop of contact pressure taking into account that busbars will expand in joints that are made during reassembly of groups.

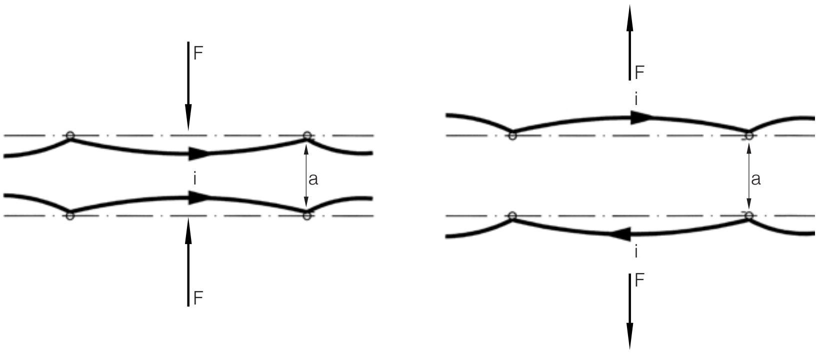




Short circuit mechanical resistance calculation of copper busbar assemblies

Rectangular sectioned copper busbar short circuit mechanical resistance is calculated as described below according to EN 60865 (1993).

Forces created by currents flowing from parallel conductors

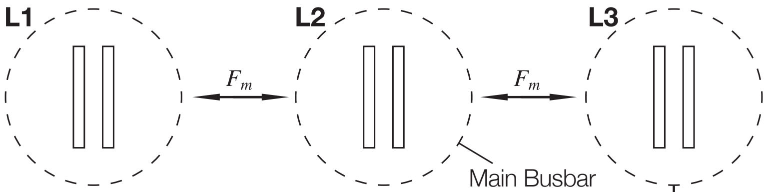


$$F \cong c \times i^2 \times \frac{\ell}{a}$$

F	;	*force*	[N]
c	;	*constant*	[N/A^2]
i	;	*current*	[A]
ℓ	;	*conductor length*	[m]
a	;	*distance between conductors*	[m]

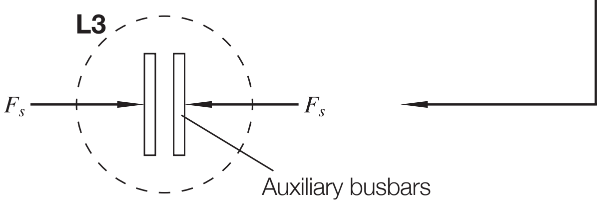
Forces generated during short circuit in switch enclosures

F_m ; forces between main busbars (phase busbars)



F_m ; forces between main busbars (phase busbars) can be in pull or push direction according to current direction flowing in adjacent phases.

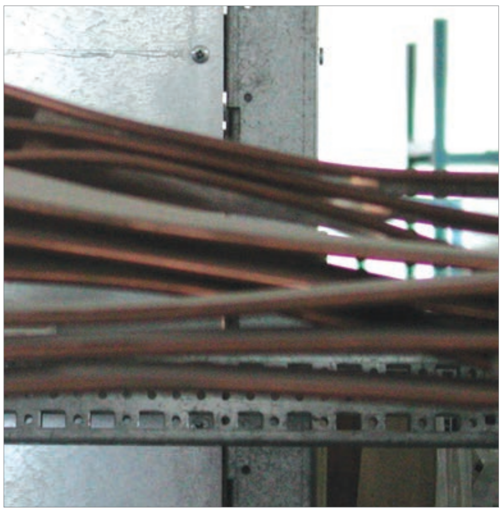
F_s ; forces between auxiliary busbars (busbars in phase)



F_s ; forces between auxiliary busbars (busbars in phase) are always in pull direction, current flowing in adjacent auxiliary busbar is always in the same direction.

When main busbars (phase busbars) are formed of a single busbar, calculations related to auxiliary busbars are not necessary. In this case, main busbar is the auxiliary busbar at the same time.

Important !
It is required for
1) Busbars themselves,
2) Support insulators
to resists generated forces.



The photograph above belongs to busbar assemblies to which B Series type tests are applied and it shows that busbars themselves are subjected to mechanical forces. It is seen that Auxiliary busbars are inclined to each other.

Calculation of force generated between main busbars

$$F_m = \frac{\sqrt{3}}{2} \times \frac{\mu_o}{2\pi} \times i_{p3}^2 \times \frac{l_m}{a_m}$$

F_m	;	*forces generated between main busbars*	[N]
μ_o	;	*magnetic field constant*	[H/m]

$$\mu_o = 4\,\pi\,10^{-7} \left[\frac{\text{H}}{\text{m}}\right] \left[1\text{H}=1\frac{\text{Nm}}{\text{A}^2}\right]$$

i_{p3}	;	*three phase symmetrical short circuit current peak value*	[A]
l_m	;	*length of main busbars between to support points*	[m]
a_m	;	*effective length between main busbars*	[m]

Comment; i_{p3} approximate calculation

i_{p3} Short circuit current peak value i_{p3}, effective value is proportionate with i''_{k3}

$$i_{p3} \leq n \times i''_{k3}$$

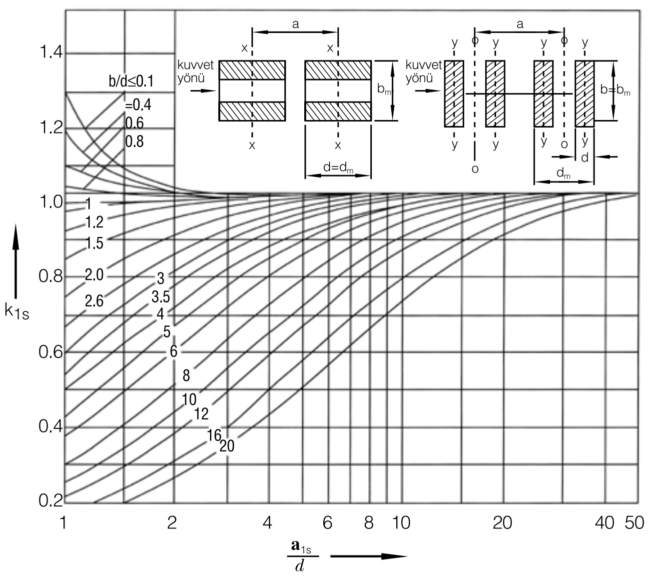
n-multiplier for an average site for IEC439-1	n
$i''_{k3} \leq$ 5kA	1,5
5kA $< i''_{k3} \leq$ 10kA	1,7
10kA $< i''_{k3} \leq$ 20kA	2
20kA $< i''_{k3} \leq$ 50kA	2,1
50kA $< i''_{k3}$	2,2

Calculation of a_m-value

In order to determine the effective distance between main busbars, In Figure-1 a_{1S}=a, b=b_m ve d=d_m is used and k_{12} is reached.

(For the formula, see . P.14)

Figure-1



Comment; i''_{k3} approximate calculation of short circuit effective value

i''_{p3} i''_{k3} value is limited to transformer specifications in the site.

i''_{k3} value is calculated approximately by using the power of the transformer feeding only the site. Calculation in worst circumstances, that is assuming there is short circuit in transformer outlet is shown below.

$$S_{nT} = \sqrt{3} \times I_{nT} \times U_n$$

$$I_{nT} = \frac{S_{nT}}{\sqrt{3} \times U_n}$$

$$U_n = 380\ [\text{V}]$$

$$I_{nT} \cong 1{,}5 \times S_{nT}\ [\text{kVA}]$$

S_{nT} ; **transformer rated power** [VA]		U_n ; **site rated power**	[V]
I_{nT} ; **transformer rated current** [A]		U_{kT} ; **site short circuit volt.**	[V]

$$U_{kT} \times i''_{k3} = U_n \times I_{nT}$$

$$i''_{k3} = \frac{U_n}{U_{kT}} \times I_{nT}$$

$$i''_{k3} = \frac{1}{\%u_k} \times I_{nT}$$

$$i''_{k3} = \frac{1}{\%u_k} \times 1{,}5 \times S_{nT}\ [\text{kVA}]$$

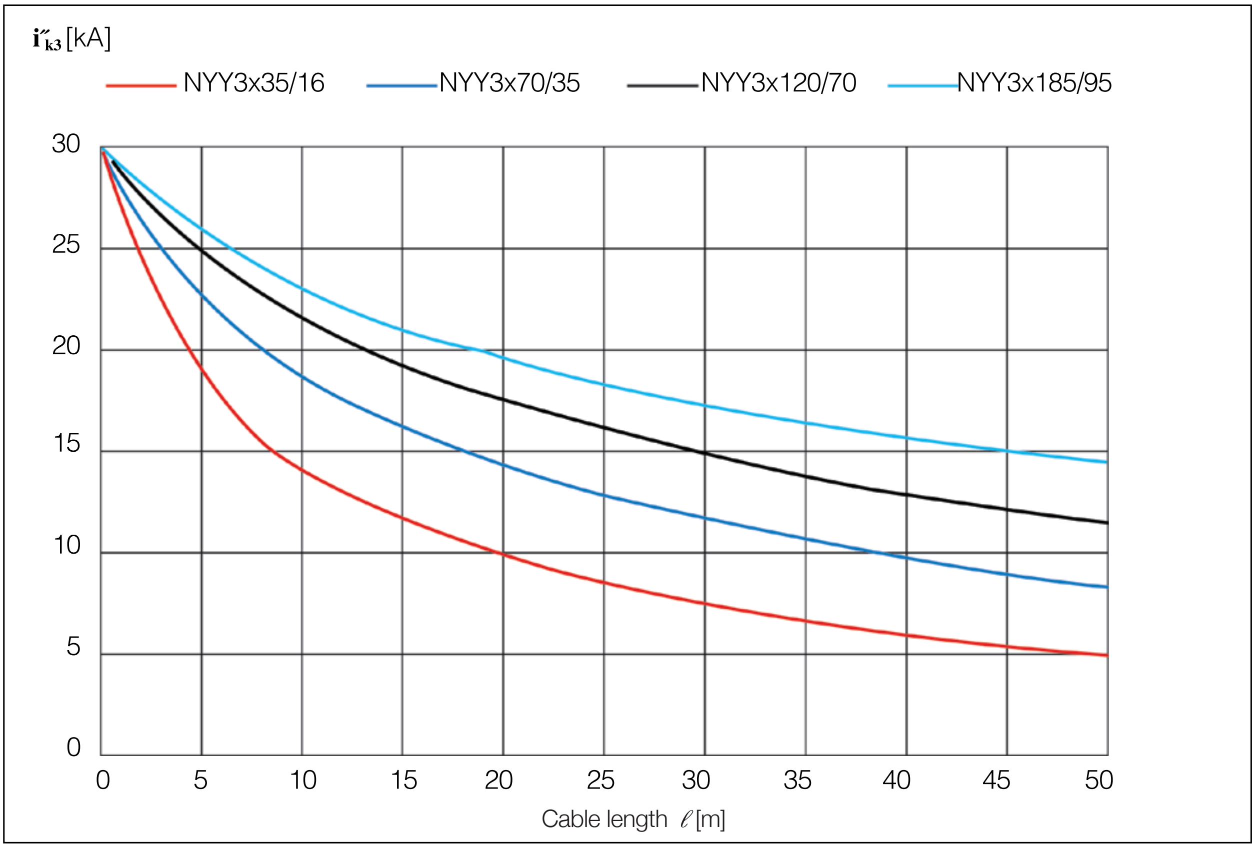
Practically;

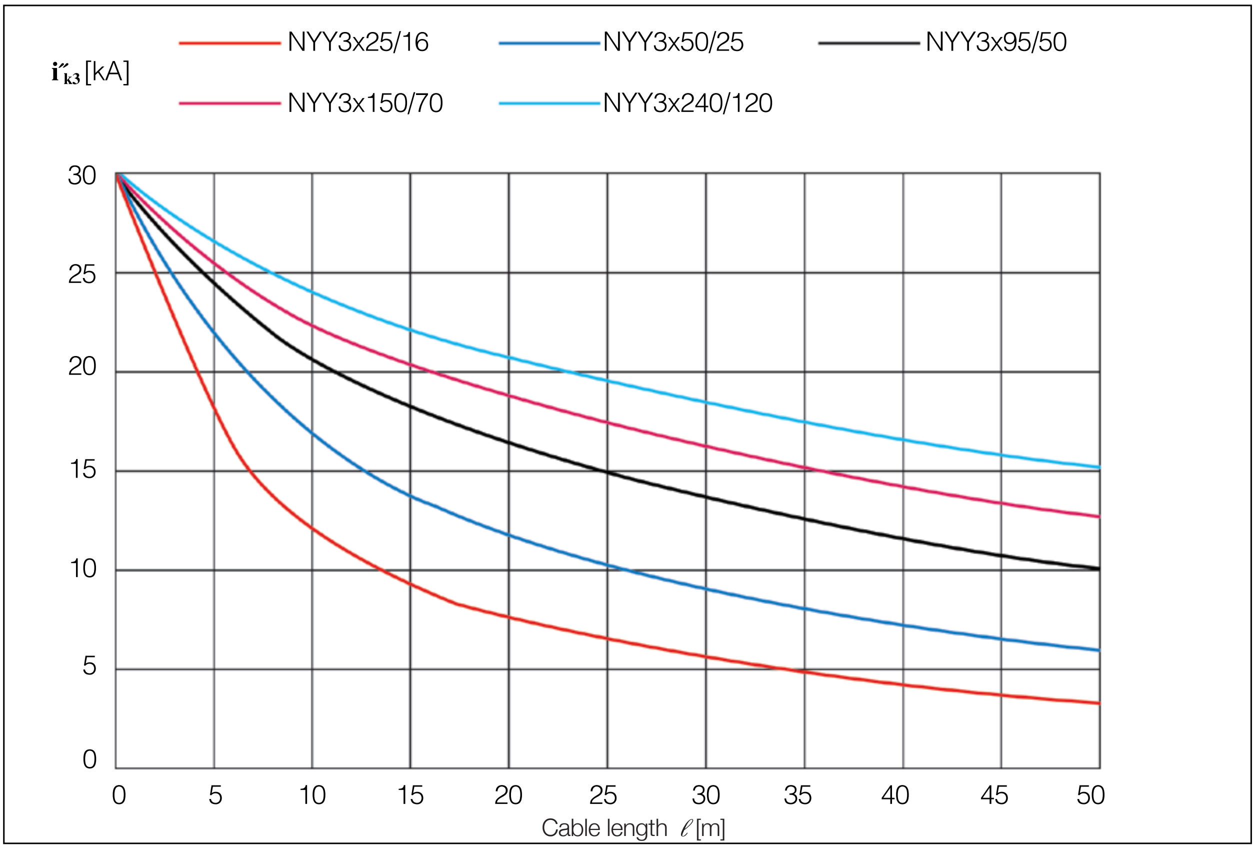
$u_k = 4$ için $i''_{k3} \cong 36 \times S_{nT}$ [kVA]
$u_k = 6$ için $i''_{k3} \cong 25 \times S_{nT}$ [kVA]

Generally, for transformers more powerful than 400kVA, it is $u_k = 6$.
Example; Maximum short circuit current effective and peak values in a site supplied by a 1000kVA transformer;

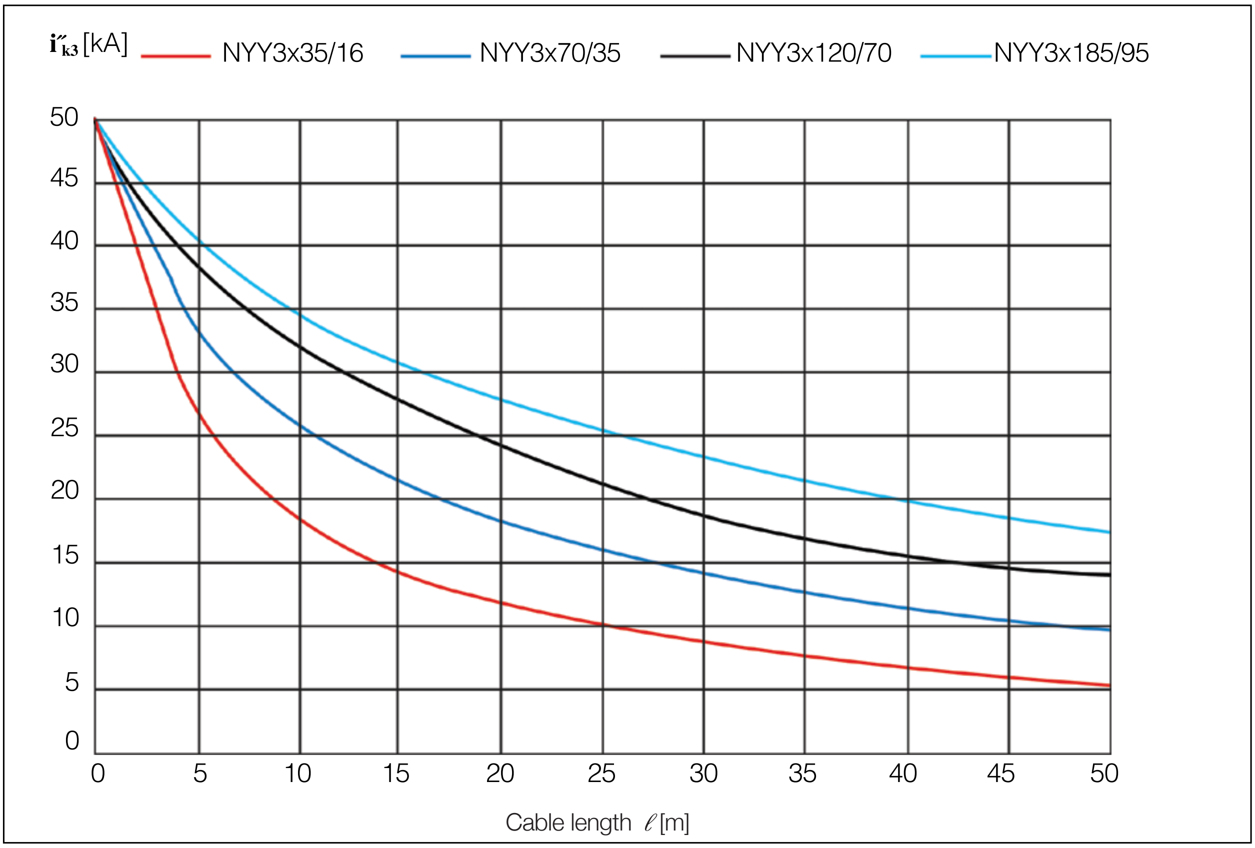
i''_{k3} = 25 [kA]
i''_{p3} = 52,5 [kA]

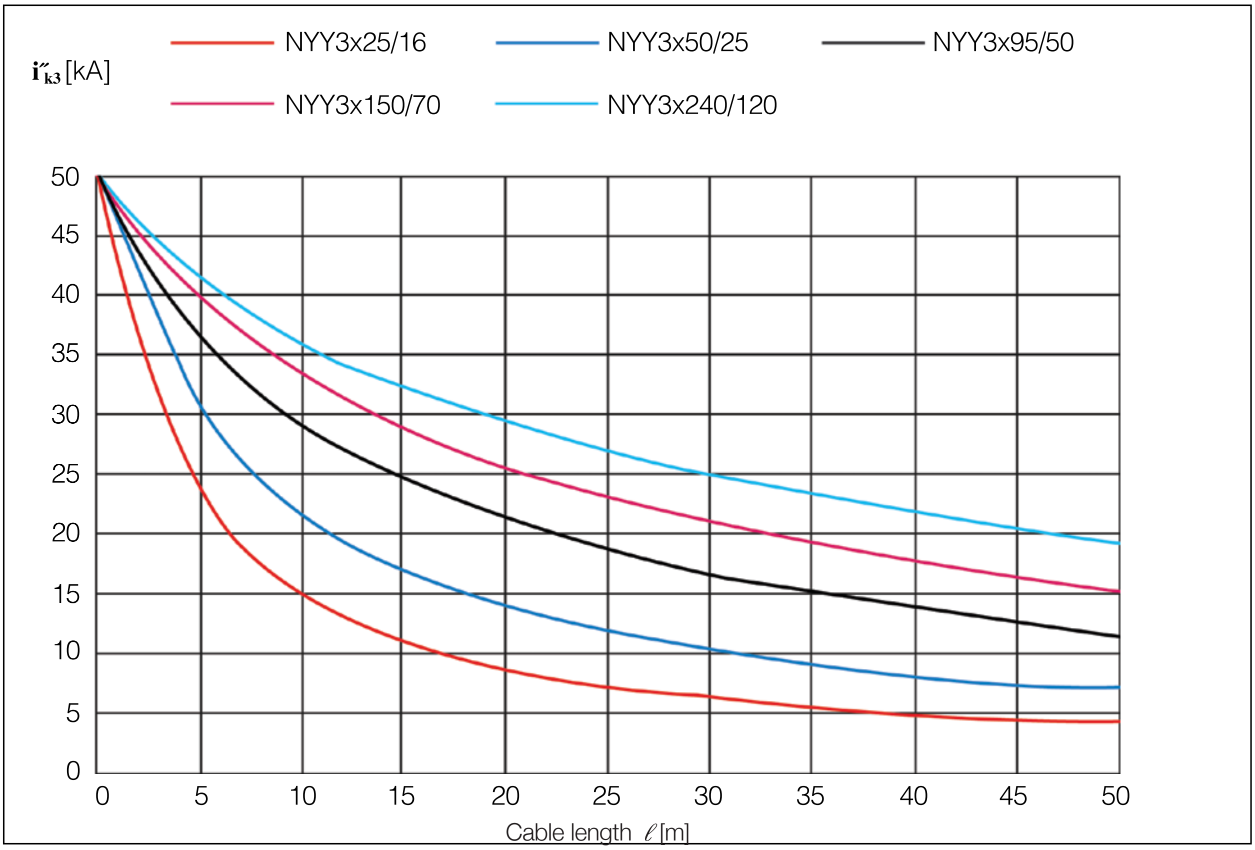
Comment; Effect of reducing short circuit current of cables





Comment; Effect of reducing short circuit current of cables





Calculation of force generated between auxiliary busbars

$$F_s = \frac{\mu_o}{2\pi} \times \left(\frac{\mathbf{i}_{p3}}{\mathbf{n}}\right)^2 \times \frac{\mathbf{l}_s}{\mathbf{a}_s}$$

F_s ; *forces generated between auxiliary busbars* [N]

μ_o ; *magnetic field constant* [H/m]

$$\mu_o = 4\,\pi\,10^{-7}\left[\frac{\mathrm{H}}{\mathrm{m}}\right]\left[1\mathrm{H}=1\frac{\mathrm{Nm}}{\mathrm{A}^2}\right]$$

i_{p3} ; *three phase symmetrical short circuit current peak value* [A]

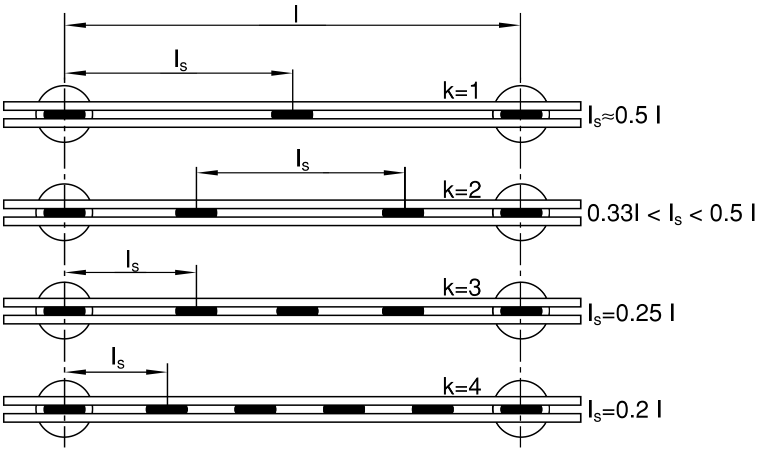
n ; *number of auxiliary busbars creating the main busbar* [1]

l_s ; *largest distance between two adjacent intermediate support element used between main busbars* [m]

a_s ; *effective length between main busbars* [m]

l_s -calculation of the value

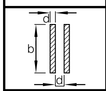
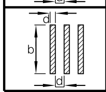
Figure-2

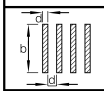
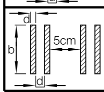


Copper joints used to provide outlet, etc. are also used as intermediate support element.

$\mathbf{a}_s$-calculation of the value

Chart-4

Order of auxiliary busbars	Busbar thickness d[mm]	Busbar Width b[mm]							
		40	50	60	80	100	120	160	200
	5	20	24	27	33	40	-	-	-
	10	28	31	34	41	47	54	67	80
	5	-	13	15	18	22	-	-	-
	10	17	19	20	23	27	30	37	43

Order of auxiliary busbars	Busbar thickness d[mm]	Busbar Width b[mm]							
		40	50	60	80	100	120	160	200
	5	-	-	-	-	-	-	-	-
	10	14	15	16	18	20	22	26	31
	5	-	14	15	18	20	-	-	-
	10	17,4	18	20	22	25	27	32	-

a_s and a_m values can also be calculated using the formula below.

$$\mathbf{k_{1s}} = \left\{ \begin{aligned} & -\left(\frac{(\mathbf{a/d})+1}{\mathbf{b/d}}\right)^3 \times \ln \frac{[(\mathbf{a/d})+1]^2+(\mathbf{b/d})^2}{[(\mathbf{a/d})+1]^2} + 2 \times \left(\frac{\mathbf{a/d}}{\mathbf{b/d}}\right)^3 \times \ln \frac{(\mathbf{a/d})^2+(\mathbf{b/d})^2}{(\mathbf{a/d})^2} - \left(\frac{(\mathbf{a/d})-1}{\mathbf{b/d}}\right)^3 \times \ln \frac{[(\mathbf{a/d})-1]^2+(\mathbf{b/d})^2}{[(\mathbf{a/d})-1]^2} \\ & + 3 \times \left[\left(\frac{\mathbf{a/d}}{\mathbf{b/d}}\right)^3 \times \ln \frac{[(\mathbf{a/d})+1]^2+(\mathbf{b/d})^2}{(\mathbf{a/d})^2+(\mathbf{b/d})^2} + \frac{1}{\mathbf{b/d}} \ln \frac{[(\mathbf{a/d})+1]^2+(\mathbf{b/d})^2}{[(\mathbf{a/d})-1]^2+(\mathbf{b/d})^2} - \frac{\mathbf{a/d}}{\mathbf{b/d}} \ln \frac{(\mathbf{a/d})^2+(\mathbf{b/d})^2}{[(\mathbf{a/d})-1]^2+(\mathbf{b/d})^2}\right] \\ & + 6 \times \left[\left(\frac{(\mathbf{a/d})+1}{\mathbf{b/d}}\right)^2 \times \arctan \frac{\mathbf{b/d}}{(\mathbf{a/d})+1} - 2 \times \left(\frac{\mathbf{a/d}}{\mathbf{b/d}}\right)^2 \times \arctan \frac{\mathbf{b/d}}{\mathbf{a/d}} + \left(\frac{(\mathbf{a/d})-1}{\mathbf{b/d}}\right)^2 \times \arctan \frac{\mathbf{b/d}}{(\mathbf{a/d})-1}\right] \\ & + 2 \times \left[\times \arctan \frac{(\mathbf{a/d})+1}{\mathbf{b/d}} - 2 \times \arctan \frac{\mathbf{a/d}}{\mathbf{b/d}} \times \arctan \frac{(\mathbf{a/d})-1}{\mathbf{b/d}}\right] \end{aligned} \right\} \times \frac{\mathbf{a/d} - \mathbf{b/d}}{6}$$

Short circuit mechanical resistance of copper busbars

Forces generated during short circuit forces causes busbars to bend. Mechanical tensions generated in these circumstances and calculation related to busbar resistance are shown below.

σ_m Bending tension on main busbars $\left[\frac{N}{m^2}\right]$

$$\sigma_m = V_\sigma \times V_r \times \beta \times \frac{F_m \times l_m}{8 \times Z_m}$$

σ_s Bending tension on auxiliary busbars $\left[\frac{N}{m^2}\right]$

$$\sigma_s = V_{\sigma s} \times V_{rs} \times \frac{F_s \times l_s}{16 \times Z_s}$$

$V_\sigma, V_r, V_{\sigma s}, V_{rs}$; *Multipliers related to dynamic forces* [1]

β ; *Multiplier related to support method* [1]

Z_m ; *Cross section inertia moment of main conductors* [m^3]

Z_s ; *Cross section inertia moment of auxiliary conductors* [m^3]

l_m ; *Distance of main busbars between two support points* [m]

l_s ; *Largest distance between two adjacent intermediate support element used between Auxiliary busbars* [m]

F_m ; *Forces generated between main busbars* [N]

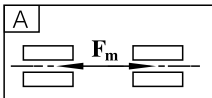
F_s ; *Forces generated between Auxiliary busbars* [N]

Comment	
$V_\sigma, V_r, V_{\sigma s}, V_{rs}$,	Multipliers related to dynamic forces is 1 if there is no "reclosing" applied in the said site. Reclosing is not carried out in short circuit cases in low voltage sites. That's why these multipliers can be ignored in low voltage applications.

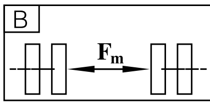
Calculation of Z_m and Z_s values Ahesaplanması

Z_s value is calculated as shown in Figure 4 according to force direction (busbar assembly Cross section axis).

Figure-4



$$Z_s = \frac{b^2 \times d}{6}$$

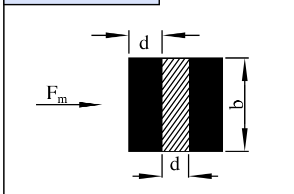


$$Z_s = \frac{b \times d^2}{6}$$

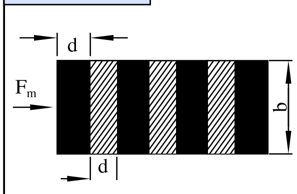
If Z_m - value force direction is A as shown in Figure-4, it is calculated by multiplying Z_s – number with auxiliary busbar number. If force direction is B as shown in Figure 4 and there is only one or no support between Auxiliary busbars, the same calculation is used. In this case, if there are two or more support elements, values in Figure 5 are used.

Figure-5

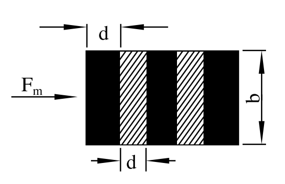
$Z_m = 0{,}867\ d^2b$



$Z_m = 3{,}48\ d^2b$



$Z_m = 1{,}98\ d^2b$



$Z_m = 1{,}73\ d^2b$

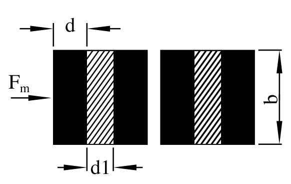
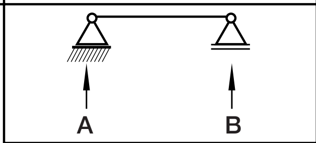
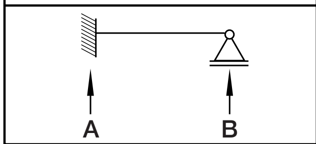
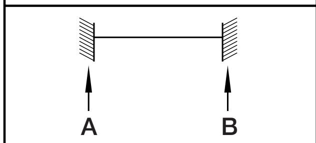
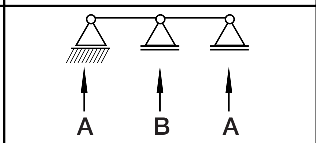
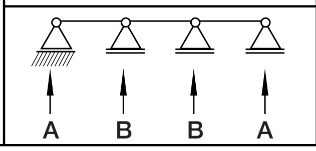


Figure 3 - ß- multiplier

	Support method	ß-multiplier
single switch enclosure		1,0
		0,73
		0,5
multiple switch enclosures with same support distances		0,73
		0,73

Comments	
ß	In insulators used in busbar assemblies of low voltage electricity switch enclosures, busbars are basically supported in two types. 1-Busbars are positioned in a way to slide on insulators and constrained between the two insulators. If there is too much support in this state, ß=0.73 can be used in general. 2-Busbars are fixed on insulators with bolts in holes opened on them. If there is too much support in this state, ß=0.5 can be used in general.

For busbars to resist short circuit forces without being deformed;

$$\sigma_{tot} = \sigma_s + \sigma_m \leq \mathbf{q} \times \mathbf{R}_{p0,2}^{min.}$$

Comments; Copper flow resistance upper and lower limit

$R_{p0,2}$

	$\mathbf{R}_{p0,2}^{min}$ $[\frac{N}{m^2}]$	$\mathbf{R}_{p0,2}^{max}$ $[\frac{N}{m^2}]$
E-Cu F25	200	290
E-Cu F30	250	360

σ_{tot} ; *Total bending tension of busbars* $[\frac{N}{m^2}]$

q ; *Plasticity multiplier* [1]

$\mathbf{R}_{p0,2}^{min.}$; *Copper flow resistance lower limit* $[\frac{N}{m^2}]$

Comments

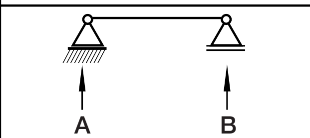
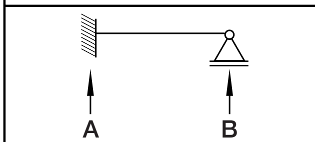
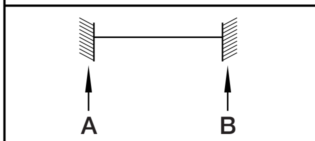
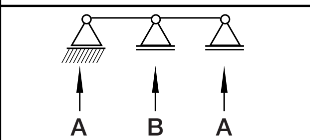
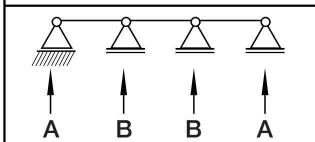
q For rectangular cross-section busbars $\mathbf{q}$=1,5

Forces acting on support points

$\mathbf{F_d}$ -Forces acting on support points; [N]

$$\mathbf{F_d} = \mathbf{V_F} \times \mathbf{V_r} \times \alpha \times \mathbf{F_m}$$

Figure 5 multiplier

	Support method	α-multiplier
single switch enclosure		A: 0,5 B: 0,5
		A: 0,625 B: 0,375
		A: 0,5 B: 0,5
multiple switch enclosures with same support distances		A: 0,375 B: 1,25
		A: 0,4 B: 1,1

V_F ; *The ratio of dynamic force on bearing point to static force* [1]

V_r ; *Proportion of a dynamic force generated during an unsuccessful three terminal reclosing to a successful one* [1]

α ; *Multiplier* [1]

F_m ; *Forces generated between main busbars* [N]

Comments

α In insulators used in busbar assemblies of low voltage electricity switch enclosures, busbars are basically supported in two types.
1-Busbars are positioned in a way to slide on insulators and constrained between the two insulators. If there is too much support in this state α= 1,1 can be used in general.
2-Busbars are fixed on insulators with bolts in holes opened on them. If there is more than three supports in this state α=0,4 can be used in general.

$\mathbf{V_F} \times \mathbf{V_r}$ Calculation of the multiplier	$\frac{\sigma_{tot}}{0{,}8 \times \mathbf{R}_{p0,2}^{max}} \leq 0{,}37$	$0{,}37 < \frac{\sigma_{tot}}{0{,}8 \times \mathbf{R}_{p0,2}^{max}} < 1{,}0$	$1{,}0 \leq \frac{\sigma_{tot}}{0{,}8 \times \mathbf{R}_{p0,2}^{max}}$
$\mathbf{V_F} \times \mathbf{V_r}$	2,7	$\frac{0{,}8 \times \mathbf{R}_{p0,2}^{max}}{\sigma_{tot}}$	1,0

Short circuit strength of insulators

If the short circuit strength of insulators is not demonstrated by means of testing, it should be demonstrated by calculation that the force on support points is less than the strength force supplied by the insulator manufacturer.

$$\boxed{F_d < F_{izolatör}}$$

Sample Calculation

Current information;

- Busbar assembly whose short circuit mechanic strength will be calculated consists of 2 pcs of busbars (with a cross-section of 100x10mm) per phase.
- Distance between phase axis is 150mm.
- Short circuit current is unknown; however it is known that the transformer supplying the entire plant has a power of 1000kVA.
- Busbar assembly was supported on two lateral planes of each switch cabinets. The widest switch cabinet has a width of 600mm.

  In light of this information, the calculation of the short circuit mechanic strength of the mentioned busbar assembly is as follows, based on certain assumptions.

Assumptions:

- Effective short circuit current can be calculated in the following way, assuming that there is short circuit right in the output terminals of the transformer:

$$\mathbf{i''}\boldsymbol{k3}\,[A] \cong 25 \times \boldsymbol{SnT}\,[kVA] = 25 \times 1000 = 25.000[A] = 25\,[kA]$$

- Busbar material is assumed to be E-Cu F30.
- It is assumed that busbars are positioned in a way to slide on insulators and constrained be tween the two insulators.
- It is accepted that no other reinforcement piece apart from the support points is used between two busbars that constitute the phase conductor or no supports are provided by making another busbar output.

Values that form the basis of the calculations;

Busbar cross-section 100 [mm] x10 [mm]
Number of busbars in the phase n=2

$$\mathbf{i''_{k3}} = 25[kA]$$

$$\mathbf{i''_{p3}} = \mathbf{n} \times \mathbf{i''_{k3}} = 2.1 \times 25[kA] = 52,5[kA] = 52,5 \times 10^3\,[A]$$

Bara Malzemesi E-Cu F30

$$\mathbf{R_{p0,2}^{min}} = 250\left[\frac{N}{mm^2}\right]$$

$$\mathbf{R_{p0,2}^{max}} = 360\left[\frac{N}{mm^2}\right]$$

$$\boldsymbol{\mu_0} = 4\pi.10^7\left[\frac{H}{m}\right]$$

$$\alpha = 1.1$$

$$\mathbf{ß} = 0.73$$

$$\mathbf{l_m} = 600mm$$

$$\mathbf{l_s} = 600mm$$

$$\mathbf{a} = 150mm$$

$\mathbf{F_{m3}} = 1801$ [N]	$\mathbf{F_{m3}} = \frac{\sqrt{3}}{2} \times \frac{\mu_0}{2\pi} \times \mathbf{i^2_{p3}} \times \frac{\mathbf{l}_m}{\mathbf{a}_m} = \frac{\sqrt{3}}{2} \times \frac{4\pi 10^{-7}\left[\frac{H}{m}\right]}{2\pi} \times (52.5\times10^3[A])^2 \times \frac{0.6[m]}{0.159[m]}$
	$\mathbf{a_m} = \frac{\mathbf{a}}{\mathbf{k}_{12}} = \frac{0.15m}{0.94} = 0.159m$ $\frac{\mathbf{b}}{\mathbf{d}} = \frac{\mathbf{b_m}}{\mathbf{d_m}} = \frac{100mm}{30mm} \cong 3.33$ $\frac{\mathbf{a}}{\mathbf{d_m}} = \frac{150mm}{30mm} \cong 5$ $\mathbf{k_{12}} \cong 0.94$ see. Figure 2

$\mathbf{F_s} = 1736$ [N]	$\mathbf{F_s} = \frac{\mu_0}{2\pi} \times \left(\frac{\mathbf{i_{p3}}}{\mathbf{n}}\right)^2 \times \frac{\mathbf{l_s}}{\mathbf{a_s}} = \frac{4\pi 10^{-7}\left[\frac{H}{m}\right]}{2\pi} \times \left(\frac{52.5\times10^3[A]}{2}\right)^2 \times \frac{0.6[m]}{47.62\times10^{-3}[m]}$
	$\frac{1}{\mathbf{a_s}} = \frac{\mathbf{k}_{12}}{\mathbf{a}_{12}} = \frac{0.42}{20mm} = \frac{1}{47.62mm}$ $\frac{\mathbf{b}}{\mathbf{d}} = \frac{100}{10} = 10$ $\frac{\mathbf{a}_{12}}{\mathbf{d}} = \frac{20mm}{10mm} = 2$ $\mathbf{k}_{12} = 0.42$ see. Figure 2

$\sigma_\mathbf{m} = 29.61\times10^6\left[\frac{N}{m^2}\right]$ $= 29.61\left[\frac{N}{mm^2}\right]$	$\sigma_\mathbf{m} = \mathbf{V}_\sigma = \mathbf{V_r} \times \beta\mathbf{x}\frac{\mathbf{F}_{m3} \times \mathbf{l}_m}{8\mathbf{Z}} = 1.0\times0.73\times\frac{1801[N]\times0.6[m]}{8\times3.33\times10^{-6}[m^3]}$
	$\mathbf{Z=nx}\frac{\mathbf{bd}^2}{6} = 2\times\frac{0.1\times0.01^2}{6}[m^3] = 3.33\times10^{-6}\ [m^3]$

$\sigma_\mathbf{s} = 39.22\times10^6\left[\frac{N}{m^2}\right]$ $= 39.22\left[\frac{N}{mm^2}\right]$	$\sigma_\mathbf{s} = \mathbf{V}_{\sigma s} \times \mathbf{V_{rs}} \times \frac{\mathbf{F_s} \times \mathbf{l_s}}{16\mathbf{Z_s}} = 1.0\times\frac{1736[N]\times0.6[m^3]}{16\times1.66\times10^{-6}[m^3]}$
	$\mathbf{Z}_s = \frac{\mathbf{bd}^2}{6} = \frac{0.1\times0.01^2}{6}[m^3] = 1.66\times10^{-6}\ [m^3]$

$\sigma_\mathbf{toplam} \leq \mathbf{q}\times\mathbf{R^{min}_{p0.2}}$	$\sigma_\mathbf{toplam} = \sigma_\mathbf{s} + \sigma_\mathbf{m} = 29.61+39.22 = 68.83\left[\frac{N}{mm^2}\right]$ $\mathbf{q}\times\mathbf{R^{min}_{p0.2}} = 1.5\times250 = 375\left[\frac{N}{mm^2}\right]$	$68.83 \leq 375$ provided
1. Result; Busbars can resist short circuit current without bending.		

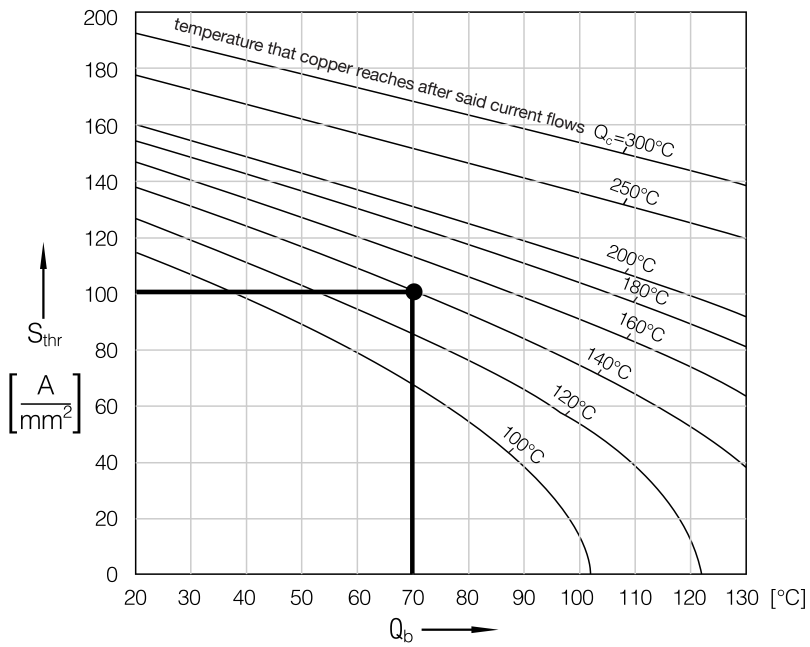
$\mathbf{F_d} = 5349$[N]	$\mathbf{F_d} = \mathbf{V_F} \times \mathbf{V_r} \times \mathbf{a} \times \mathbf{F_m} = 3.7 \times 1.1\times1801$[N]
	$\mathbf{V_F} \times \mathbf{V_r} \cong 2.7$ ⟷ $\frac{\sigma_\mathbf{toplam}}{0.8\times\mathbf{R^{max}_{p0.2}}} \leq 0.37$ $\alpha = 1.1$ $\frac{\sigma_\mathbf{toplam}}{0.8\times\mathbf{R^{max}_{p0.2}}} = \frac{68.83}{0.8\times360} = 0.239$
2. Result; Insulators need 5349 [N] (approximately 535kg) peak force in order to resist short circuit current.	

Short circuit thermic resistance calculation of copper busbar assemblies

Short circuit currents can heat copper busbars up to high temperatures. Temperature level reached after short circuit is proportionate with short circuit period and the temperature at which short circuit starts. Allowable maximum temperature for copper busbars is 200°C.
Maximum current amount that can flow from a busbar assembly after short circuit according to EN 60865 (1993) is calculated as stated below depending on short circuit time. Here, calculation is made with current intensity values in order to be independent of cross section calculations used in the said busbar assembly.

$$S_{th} \leq S_{thr} \sqrt{\frac{T_{kr}}{T_k}}$$

S_{th}	;	*Thermic equivalence short period current intensity (effective value)*	$\left[\frac{A}{m^2}\right]$
S_{thr}	;	*Rated short period current intensity for 1 sec (effective value)*	$\left[\frac{A}{m^2}\right]$
T_k	;	*short circuit period*	[s]
T_{kr}	;	*rated short period*	[s]



temperature of the copper before said current flows

Sample calculation:

Calculation of maximum short circuit current that can flow for 3 seconds from a busbar assembly that contains two 100mmx10mm copper busbars that are allowed to heat up to 70°C in operating conditions and 140°C in short circuit condition in each phase is shown below.

$$\frac{i''_{k3}}{A} \leq S_{thr} \times \sqrt{\frac{T_{kr}}{T_k}} \qquad \textit{A; total conductor cross section } [\mathrm{mm}^2]$$

$$\frac{i''_{k3}}{2\times100[\mathrm{mm}]\times10[\mathrm{mm}]} \leq 100\left[\frac{A}{mm^2}\right] \times \sqrt{\frac{1[s]}{3[s]}}$$

$$i''_{k3} \leq 2\times100[\mathrm{mm}]\times10[\mathrm{mm}]\times100\left[\frac{A}{mm^2}\right] \times \sqrt{\frac{1[s]}{3[s]}}$$

$$i''_{k3} \leq 115[\mathrm{kA}]$$

Comments

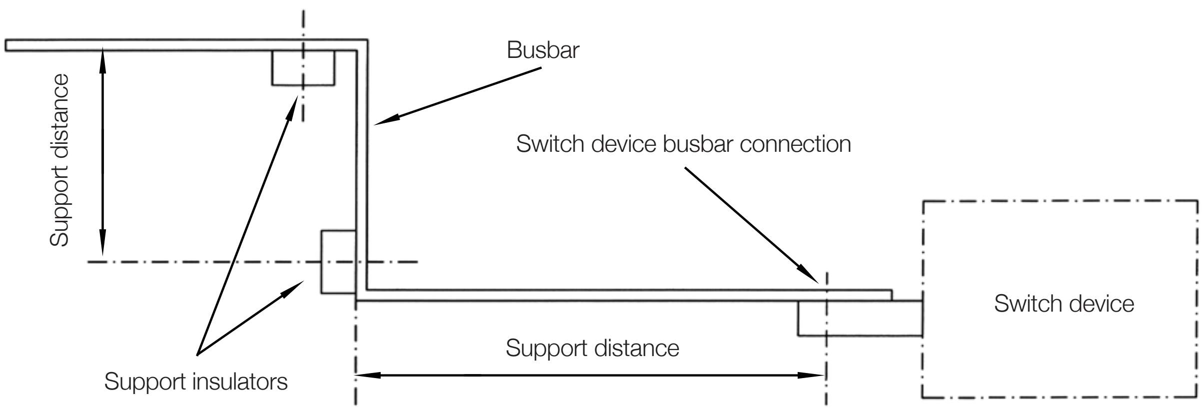
In low voltage electricity switch enclosure enclosures, the 200°C limit that is generally set for copper is not forced. In many applications, there are measures to ensure that short circuit currents end in 1 sec.

Besides the thermic resistance of copper busbars, another important issue is the resistance of insulator material that is in contact with them. The said heating is brief. In this context, short term thermic resistance of insulator material must be high enough.

Use of type tested isolators in type tested switch enclosures

IEC 61439-1:2011 standard that is used to prove technical capability of switch enclosures describes the tests to be applied on switch enclosures in details.
The test related to proving short circuit resistance among the said tests is described in section 10.11 of this standard.
B Series insulators' short circuit resistance is proven with "verification by testing" method.
IEC 61439-1:2011 standard article 10.11.4 describes "verification by comparison with reference design". Accordingly, evaluation of rated short circuit resistance current of board and circuits must be carried out by comparing a board verified by testing" with the board to be evaluated. Verification evaluation of main circuits of a board must be according to "Annex P" section, i.e. IEC 60865-1 of the standard. Each of the circuits of the board to be evaluated in addition must meet the specifications below.
Are the short circuit protection assemblies of each circuit of the board to be evaluated, the same and better limiting characteristics taking assembly manufacturer data as basis ($I^2.t.I_{pk}$) equivalent to same reference design such as manufacturing and series?

- If the board to be evaluated includes a housing, does the reference design include one when verified by testing?
- Does the housing of the board to be evaluated have the same design, type and same dimensions at least?
- Do the cells of each circuit of the board to be evaluated have the same mechanical design as the reference design and same dimensions at least?



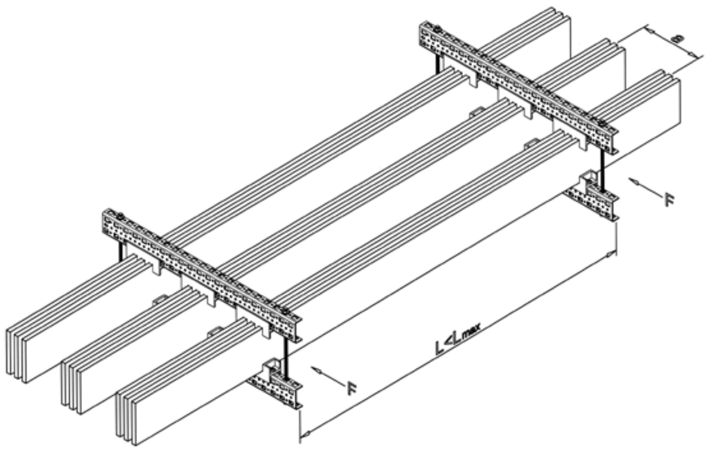
B serıes type tested isolators

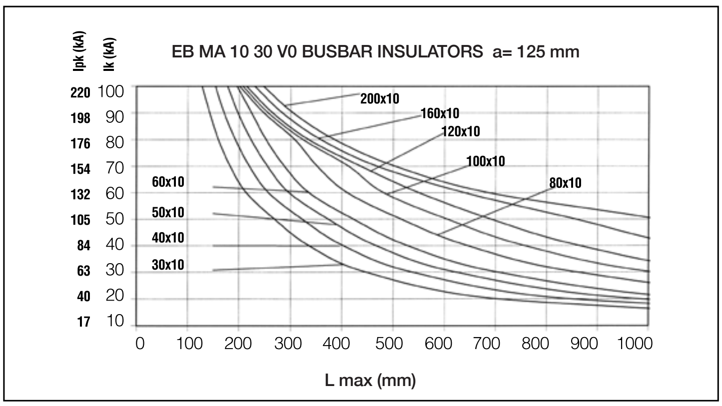
B Series low voltage insulators are designed by EAE. They are subjected to approximately 80 circuit type tests in IPH Berlin and KEMA Netherlands laboratories. There are various types of insulators in different circuit current values in B Series to be used for different purposes and methods.

B Series insulators have modular design to meet all kinds of needs for low voltage electricity switch enclosure busbar applications. Distances between phases can be changed.

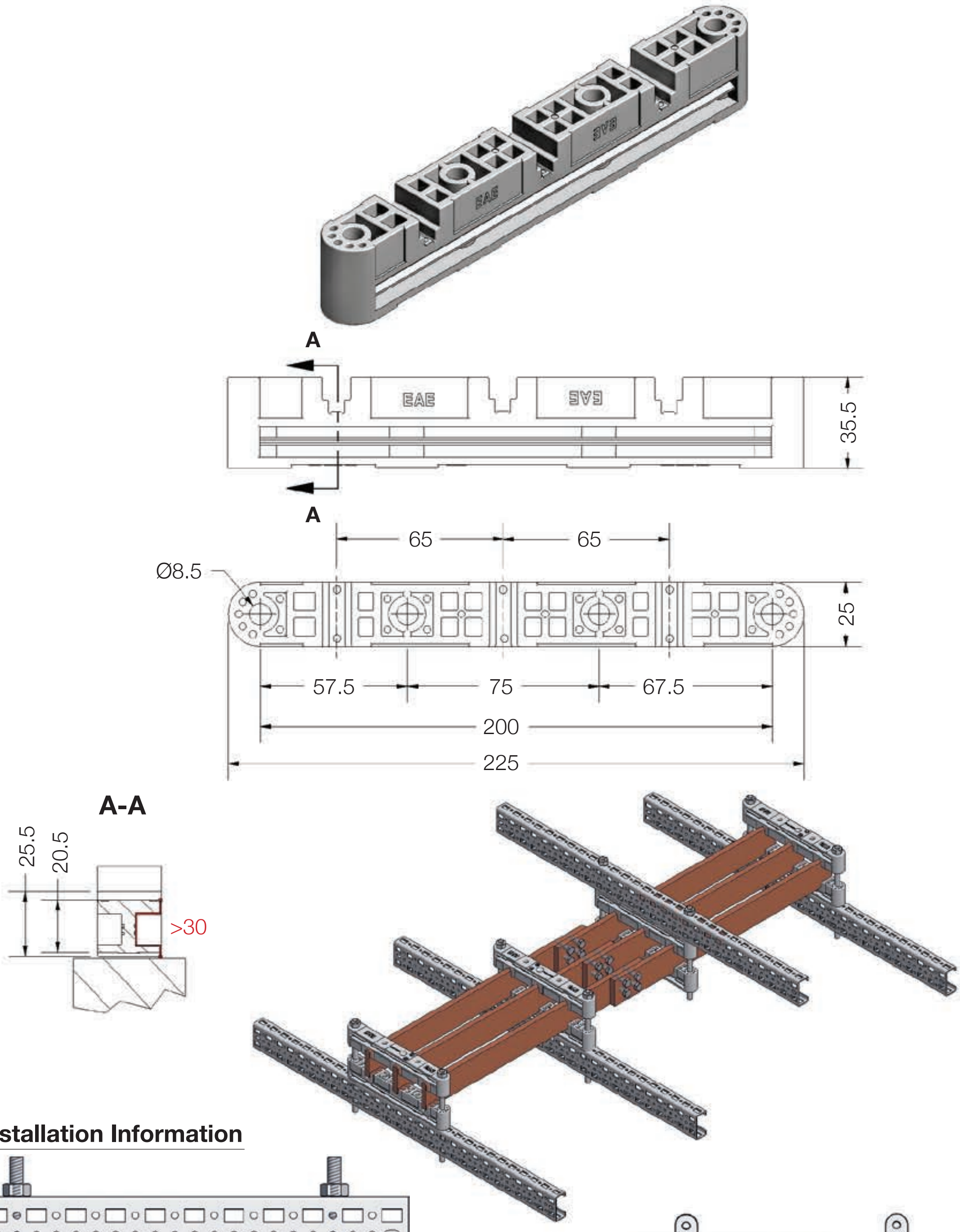
In order to use short circuit type tested B Series insulators in partially type tested switch enclosures by comparison with calculation, requirements stated in article 10.11.4 of IEC 61439-1:2011 standard must be met.

1) B Series Insulators are tested in very high short circuit currents. The short circuit current that each insulator type is tested at is given in related technical specifications page. There are insulators resisting maximum 150kA.
2) Conductive current intensities related to thermic resistances of B Series insulators during type tests are given in related technical specifications page. Insulator thermic resistance can be proven when desired by calculating compared busbar assembly current intensity. During this calculation, it can be seen that very high current intensities are used in type tests.
3) Material and manufacturing quality of B Series insulators is under EAE warranty.
4) It is mandatory for switch devices to be connected to busbar assemblies that will be compared to be type tested and that busbar connections made with them are compliant with technical documents of manufacturers.
5) Short circuit resistance of the said busbar assembly must be proven by calculating according to IEC-60865-1.
Also, there are graphics that show maximum support gaps for distances between different phases on related technical specifications pages.

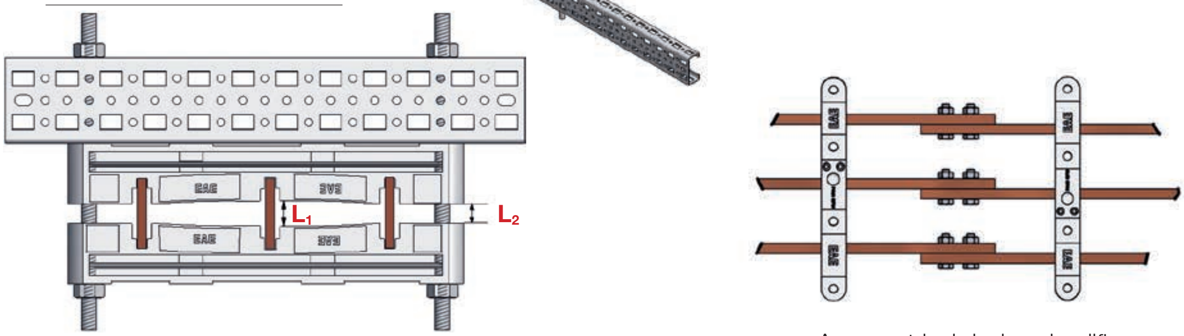




EG PA 15 13 Product Description



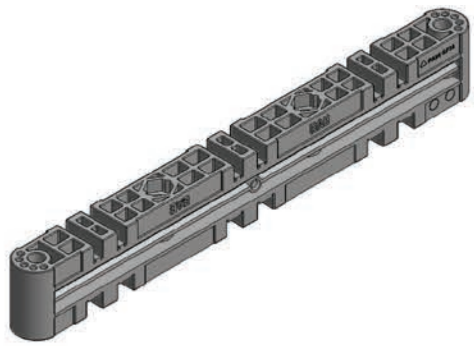
Installation Information

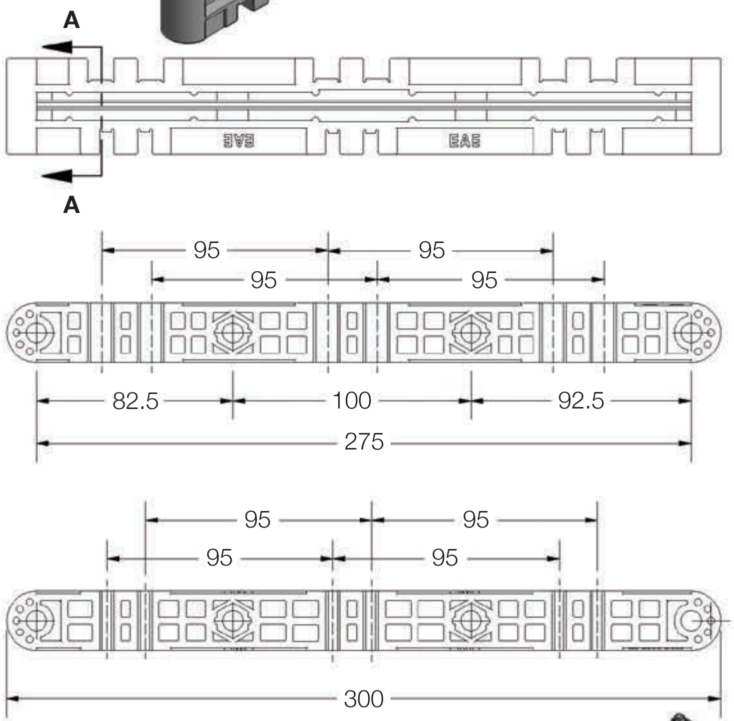


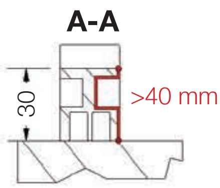
• Boltthat connects two insulators must be tightened using $L_1 = L_2^{\pm 1,0\,mm}$ formula.

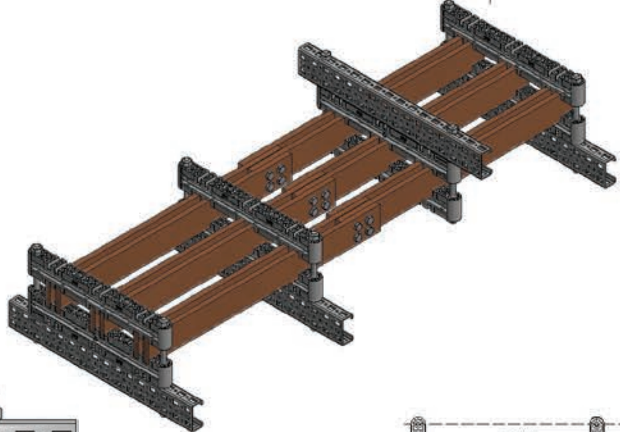
• Asymmetrical design simplifies attachment procedures.

EG PA 15 23 Product Description

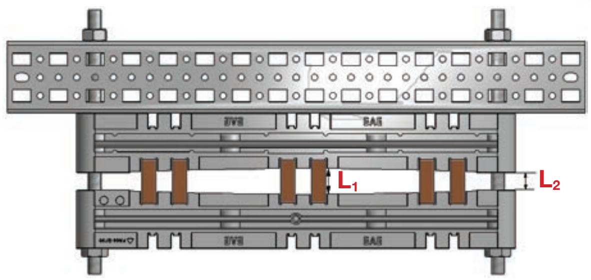




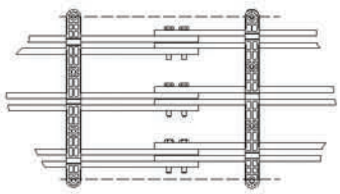




Installation Information



- Boltthat connects two insulators must be tightened using $L_1 = L_2^{\pm 1,0\,mm}$ formula.



- Asymmetrical design simplifies attachment procedures.

PM MA / MB / MC GENERAL FEATURES

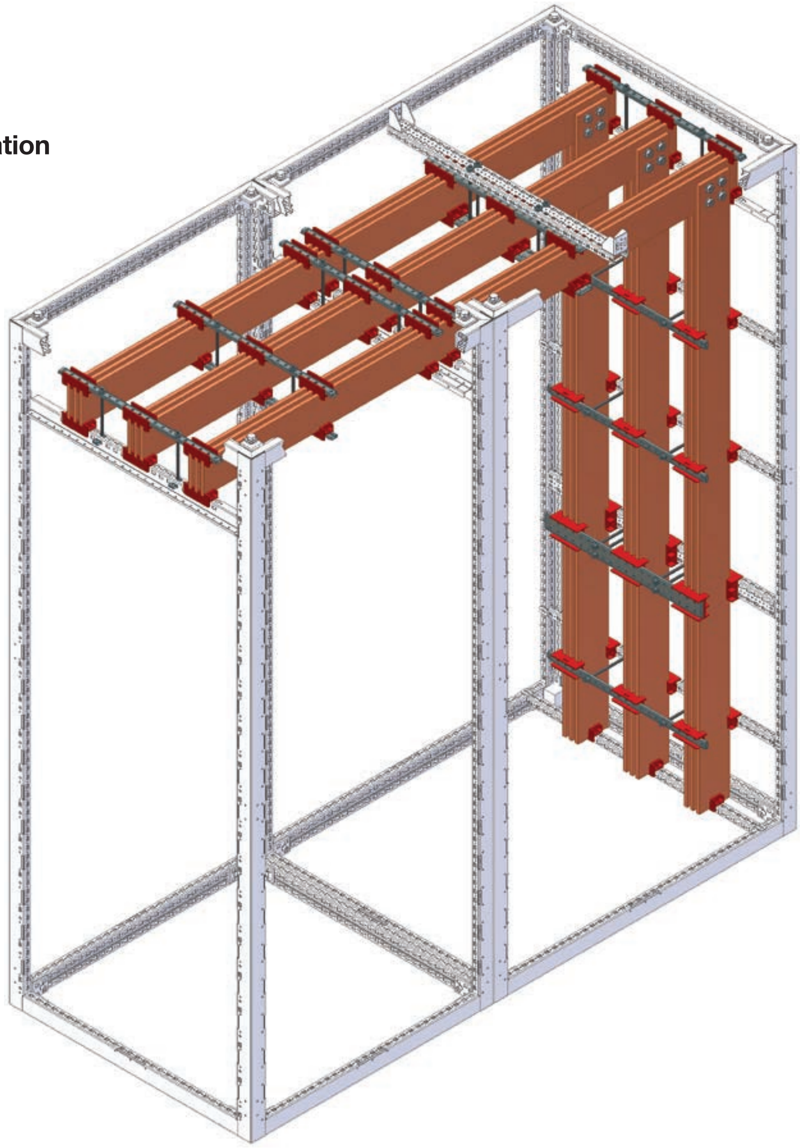
Specifications

- Designed to be used with busbars of 5mm thickness.
- Material: fiberglass reinforced polycarbonate
- Does not discharge halogen gas when burned (halogen-free)
- Fire resistant V0 according to UL94
- Tested maximum short circuit effective current 100kA
- Continuous operating temperature maximum 150°C
- Maximum current intensity applied in type tests 165 165 (A/mm^2)
- Distances between phases can be increased in 25mm increments after 75mm.
- Maximum support distances based on short circuit currents for different phase distances are given in P.28 and P.29.

Tension Insulation Specifications

- Shortest walking distance is 16mm.
- Material CTI value 175V
- Material group IIIa
- Rated insulation tension: Max. 1000V for contamination class 3

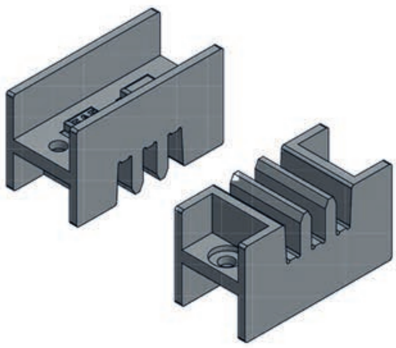
Example Configuration

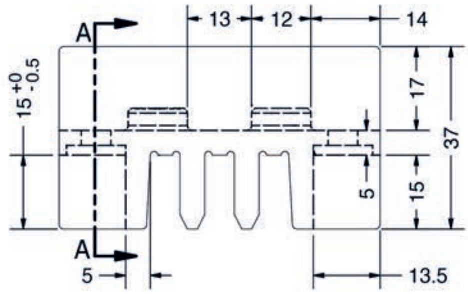


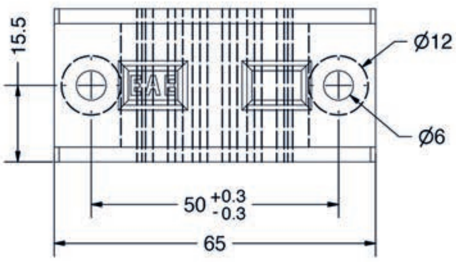
PM MC 10 3 4 T2 A200

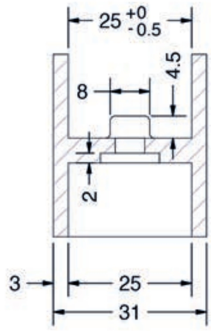
- PM MC — Isolator Type
- 10 — Busbar Section
- 3 — Busbar Number
- 4 — Pole Number
- T2 — Profile Number
- A200 — Distance Between Phases

PM MC 0531 INSULATOR SET



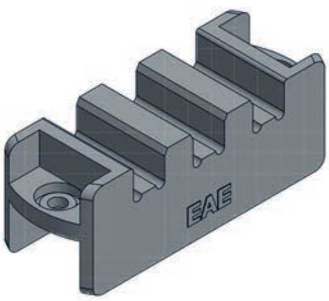


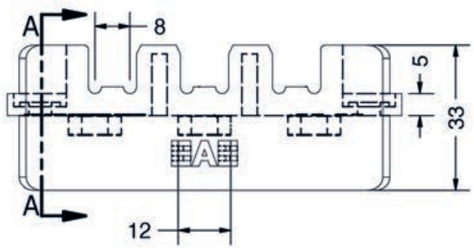


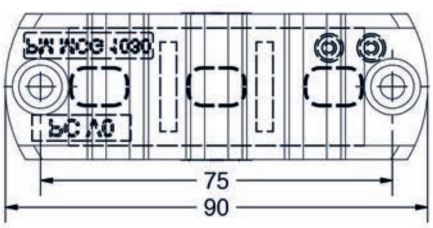


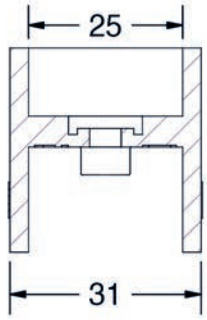
Detail A-A

PM MC 1031 INSULATOR SET



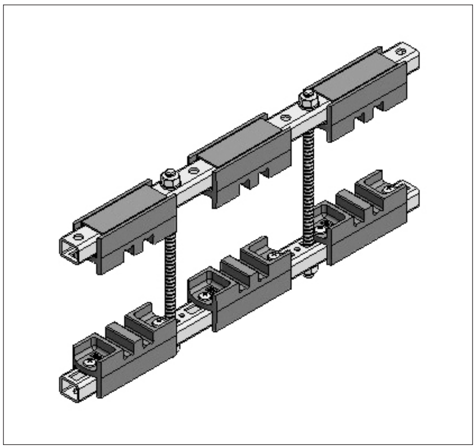


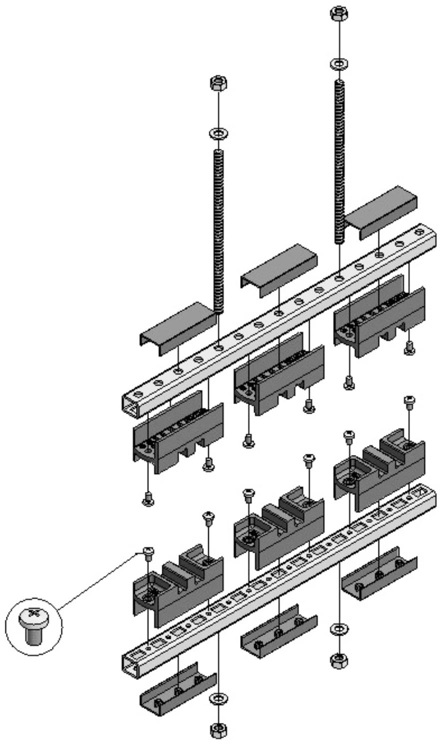




Detail A-A

PM MA 1023 A125





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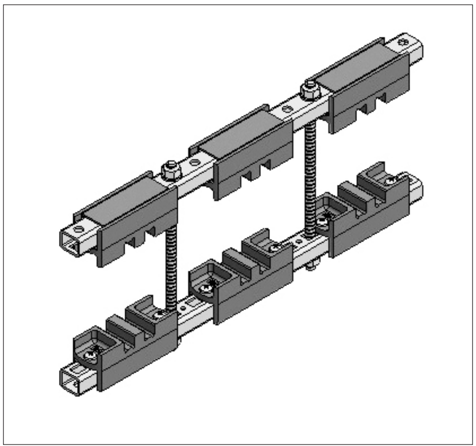

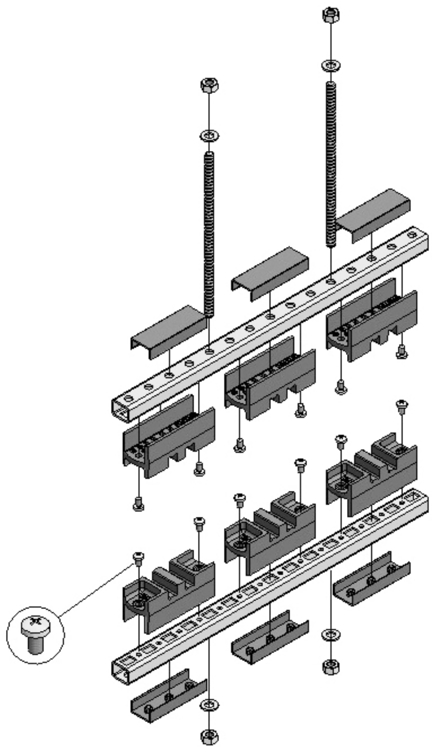

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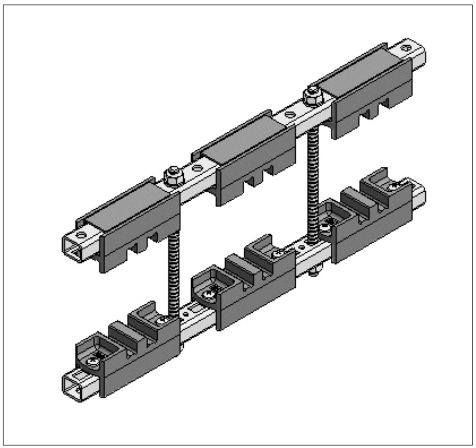
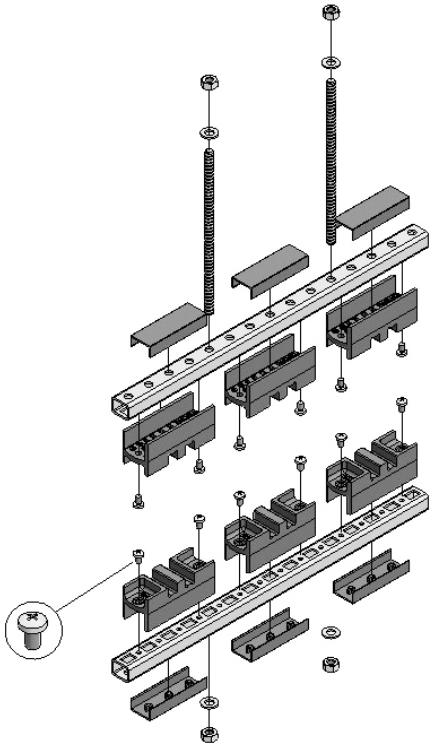
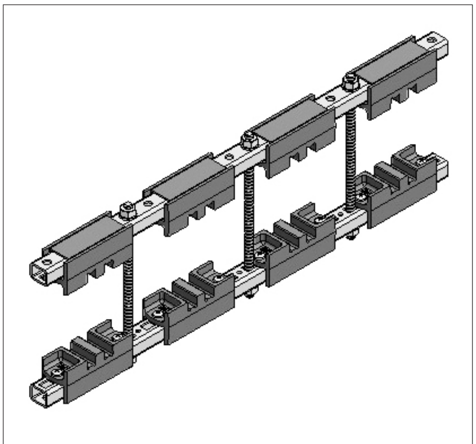
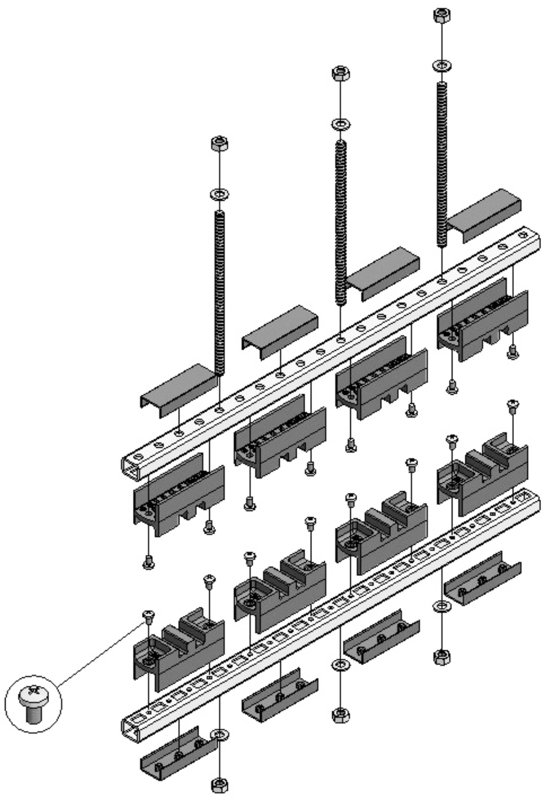




PM MA 1024 A125





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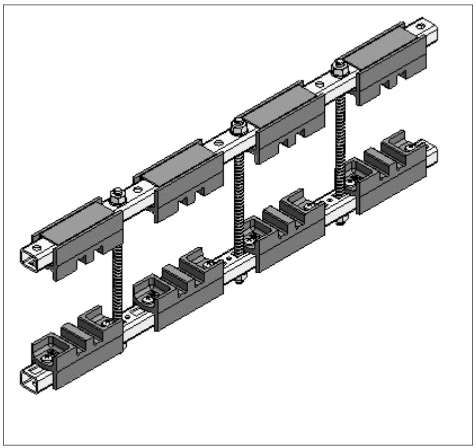

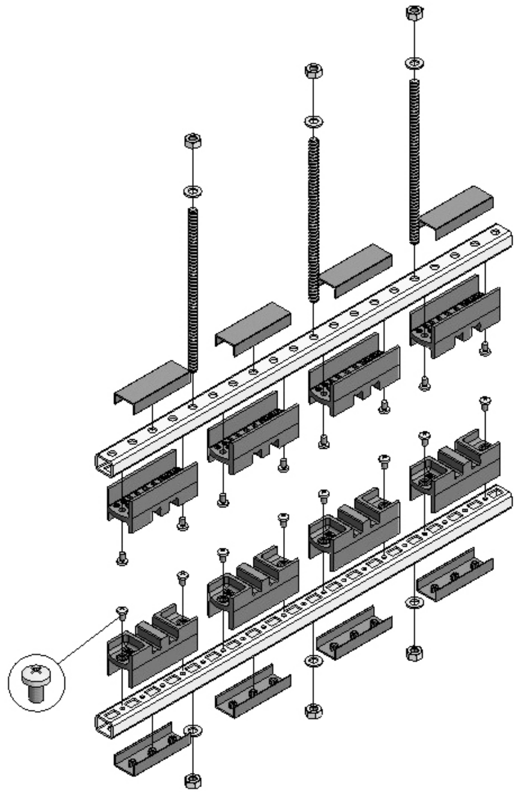

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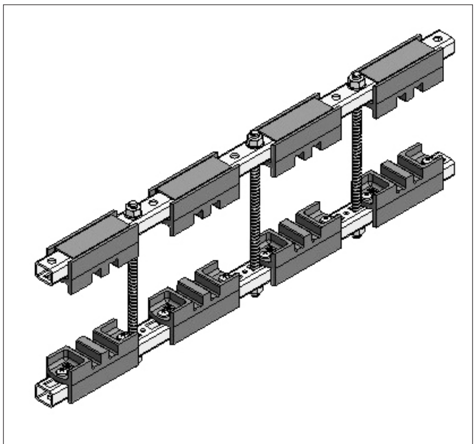

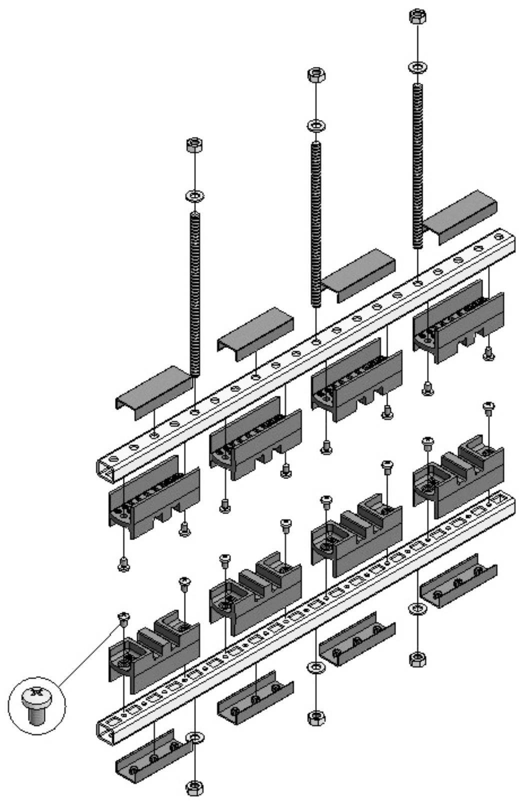

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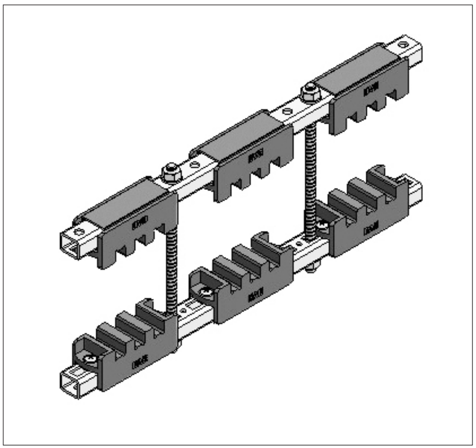

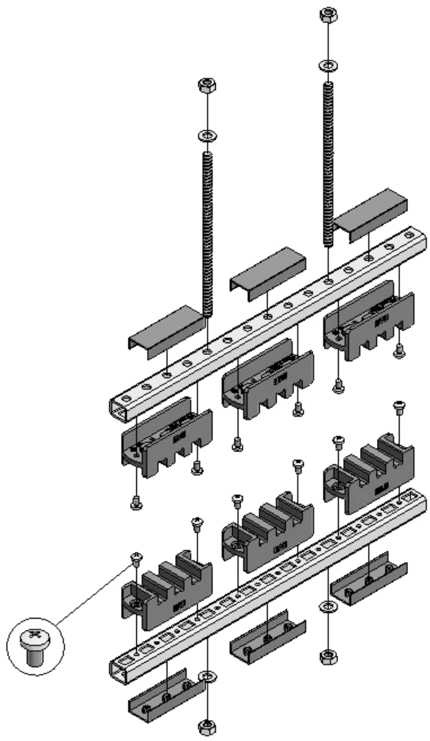

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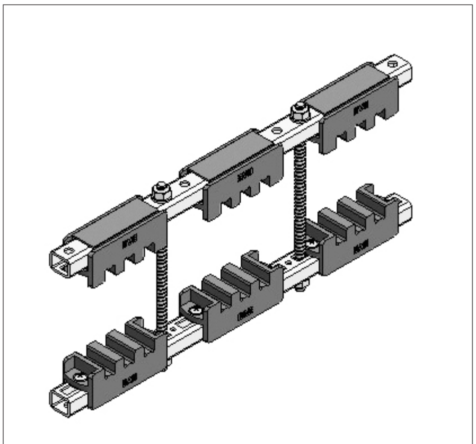

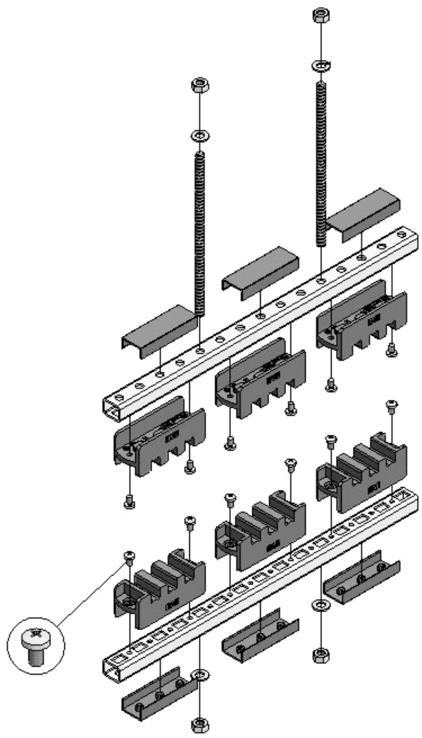

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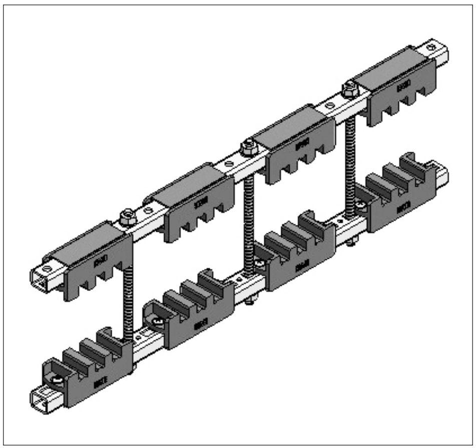

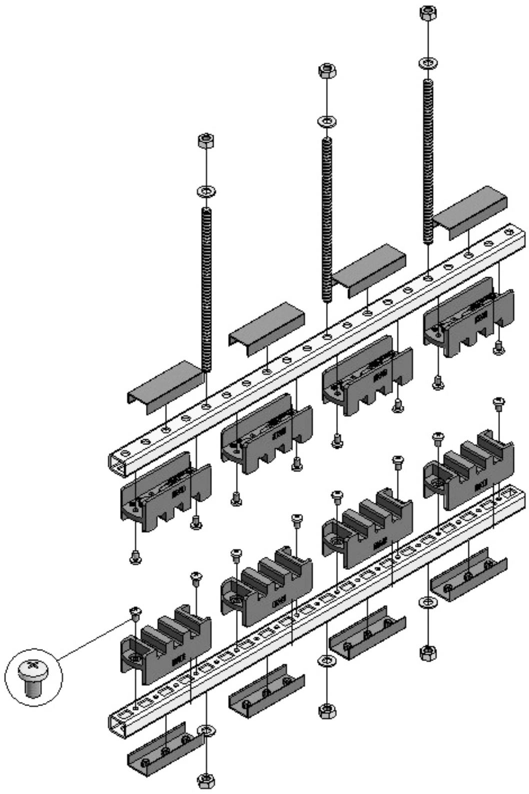

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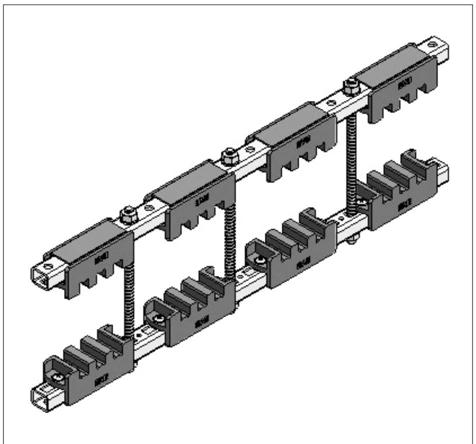

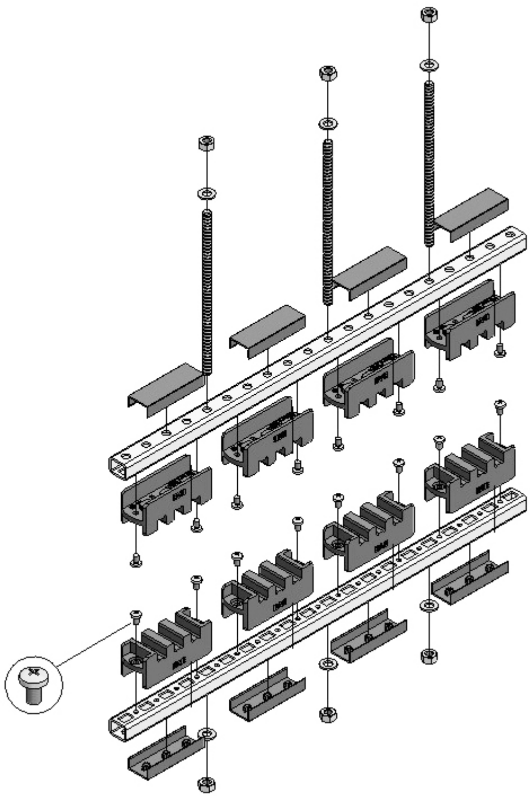

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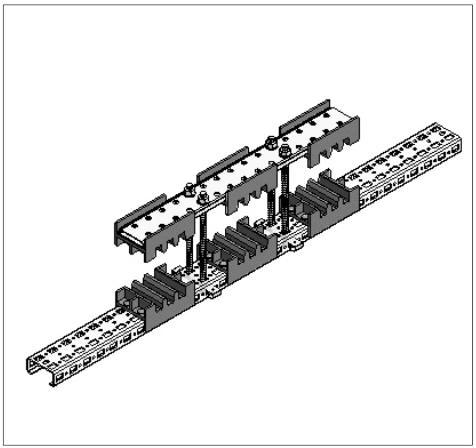

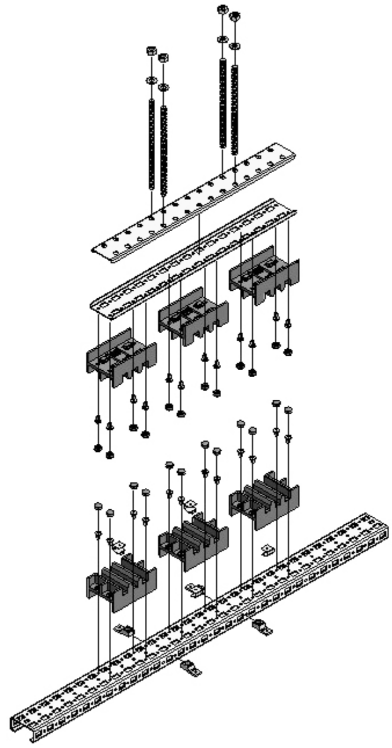

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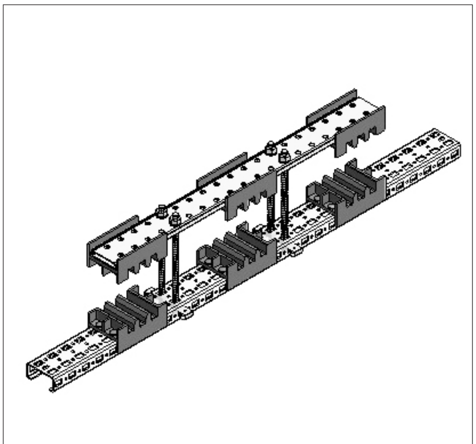

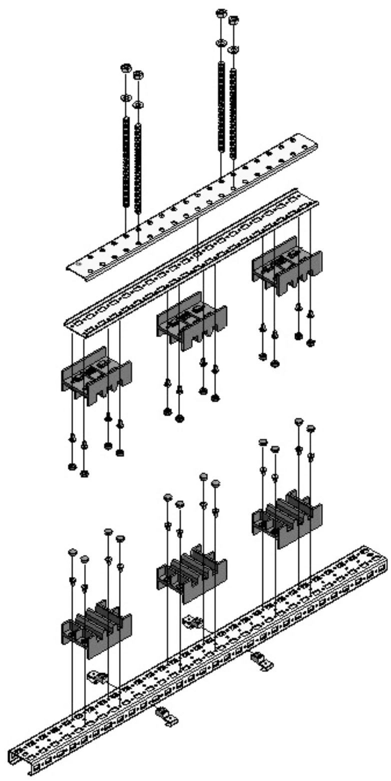

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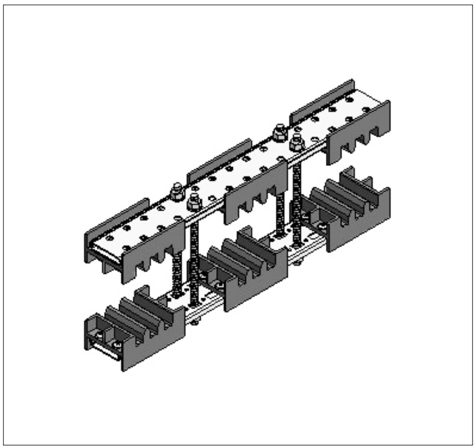

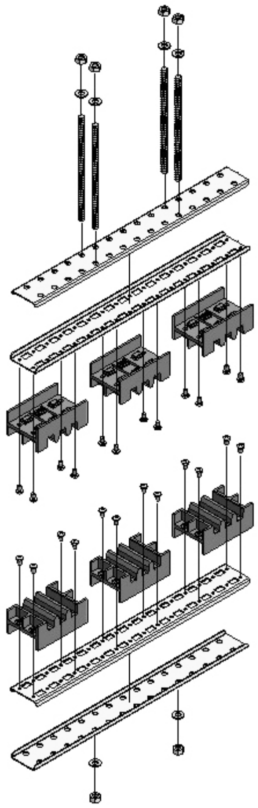

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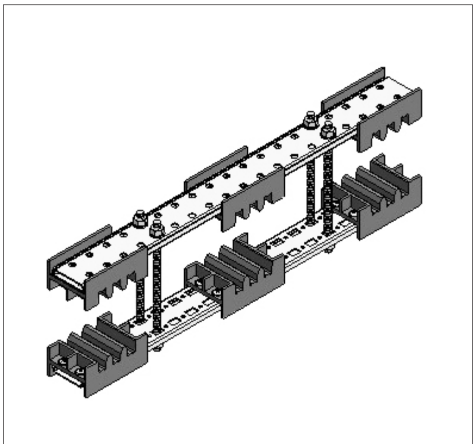

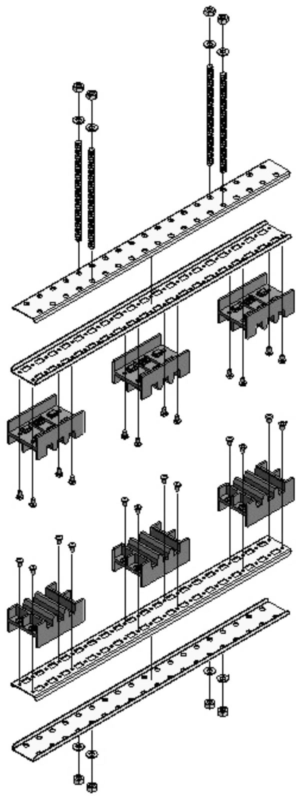

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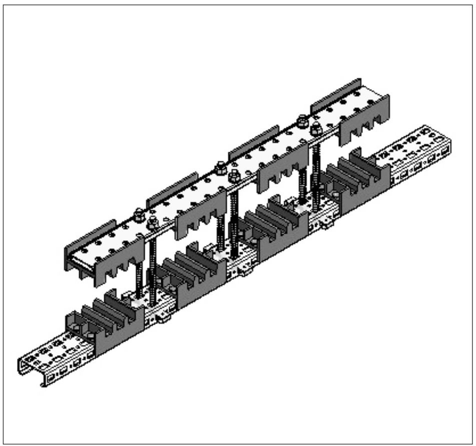

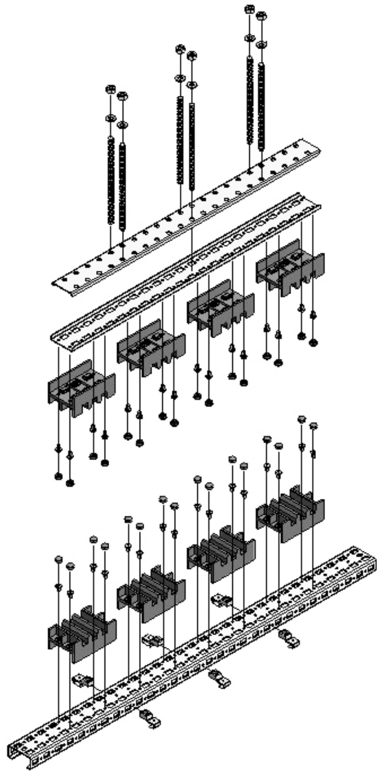

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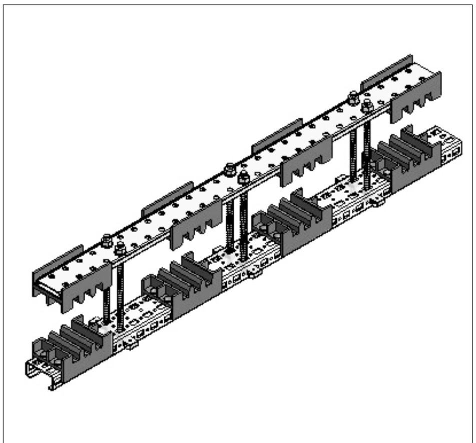

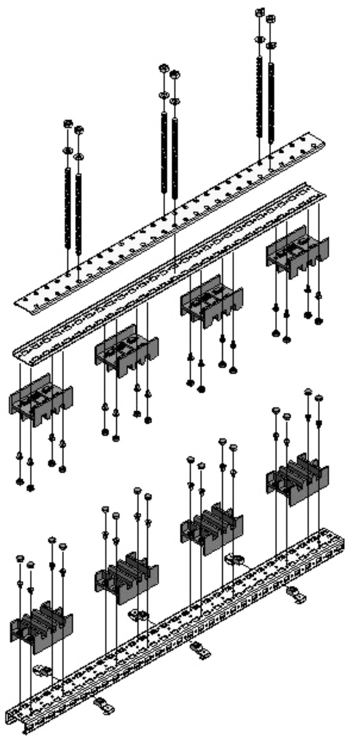

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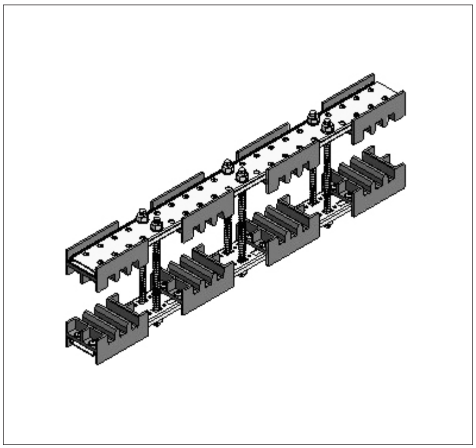

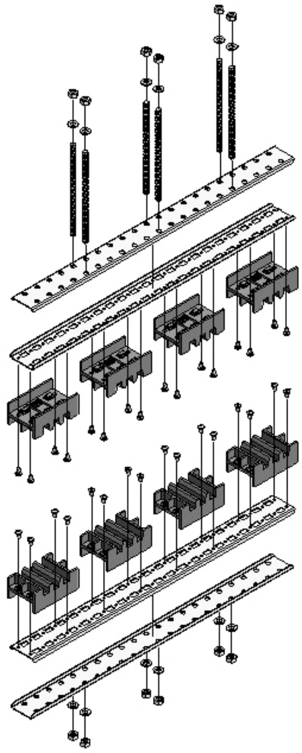

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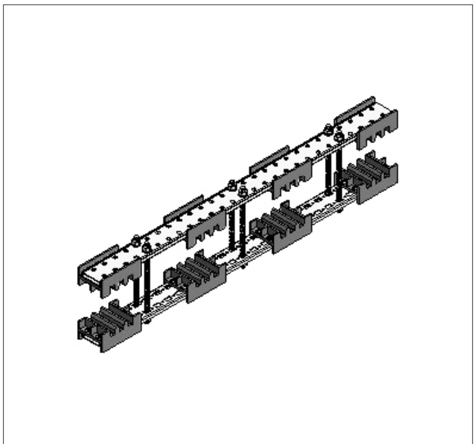

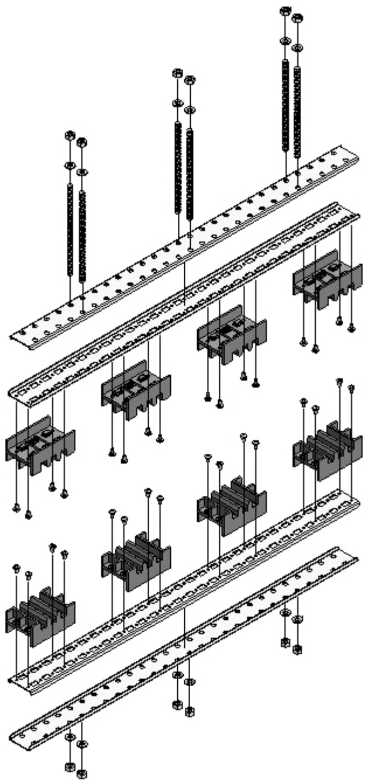

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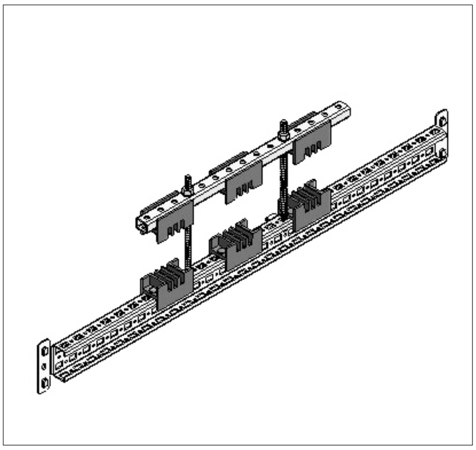

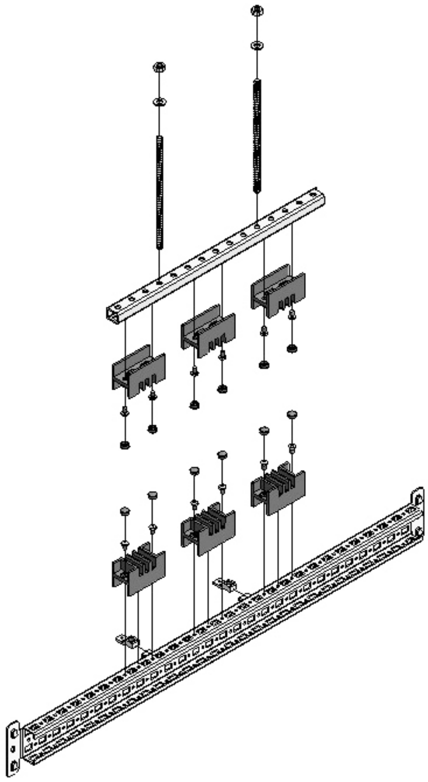

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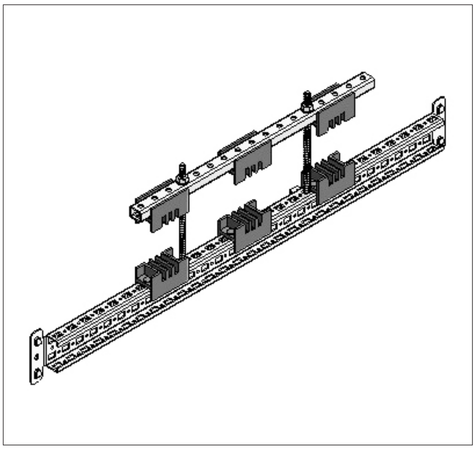

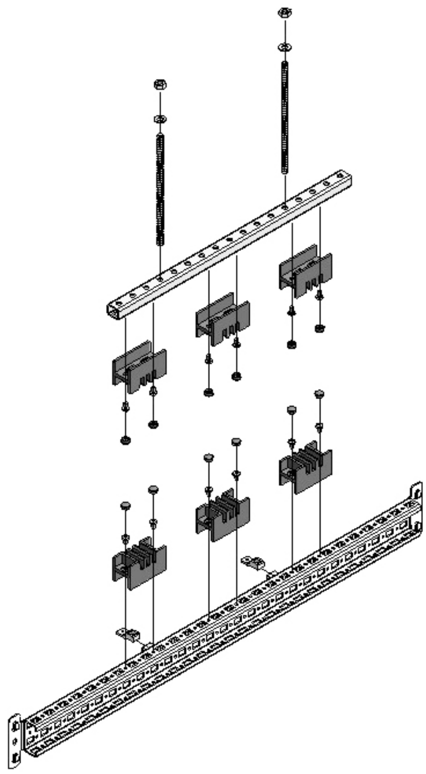

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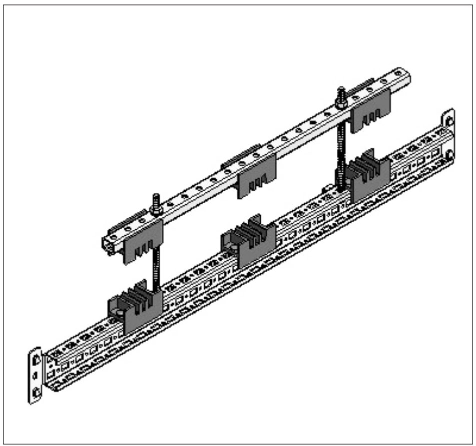

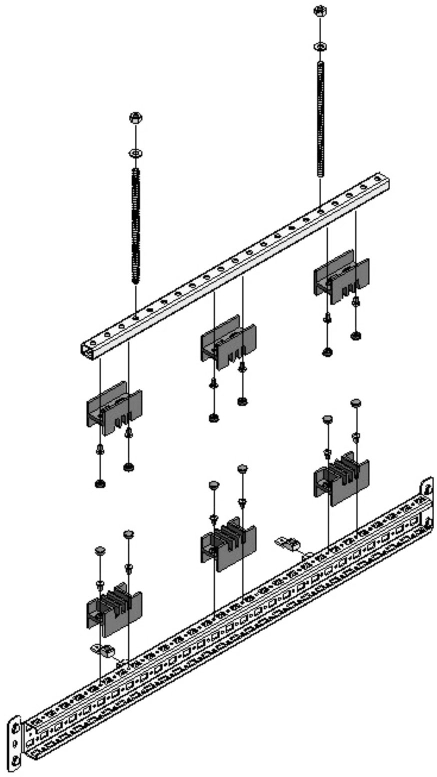

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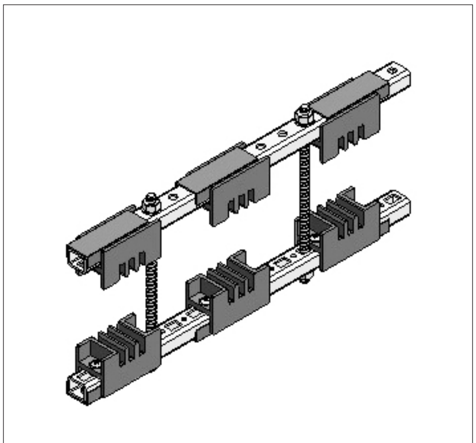

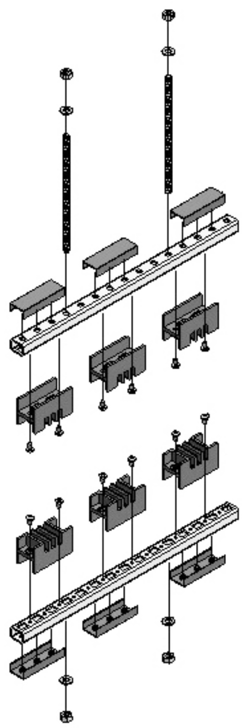

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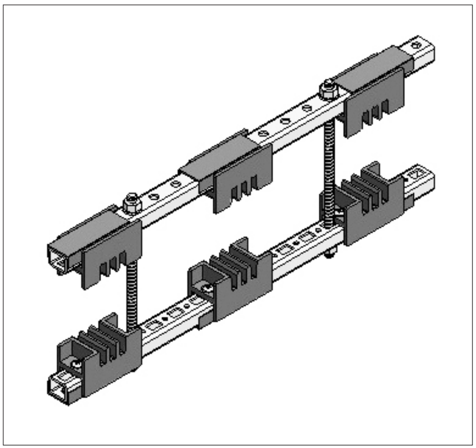

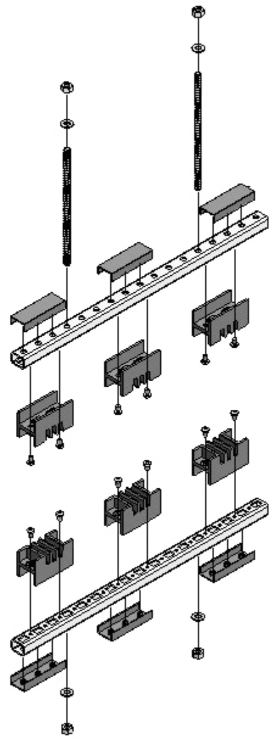

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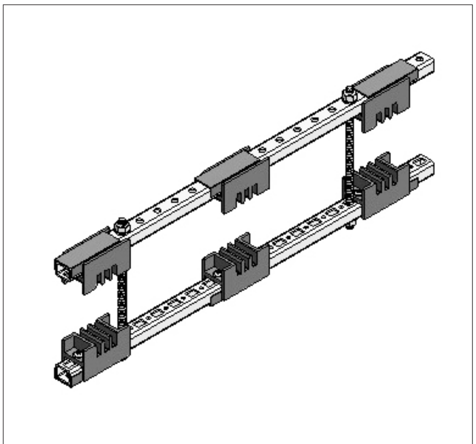
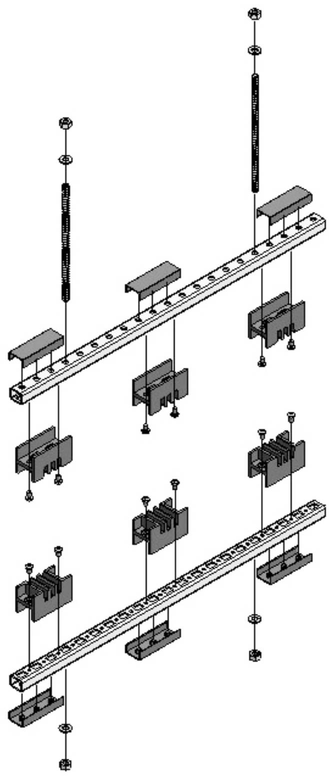
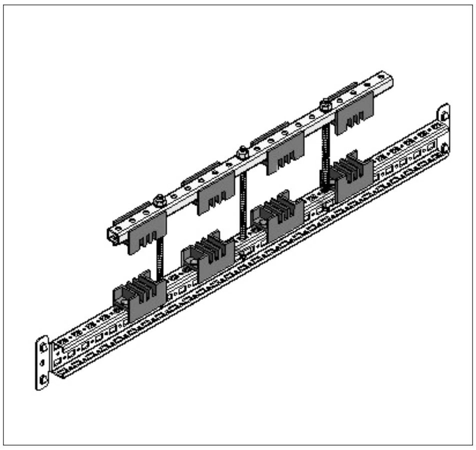
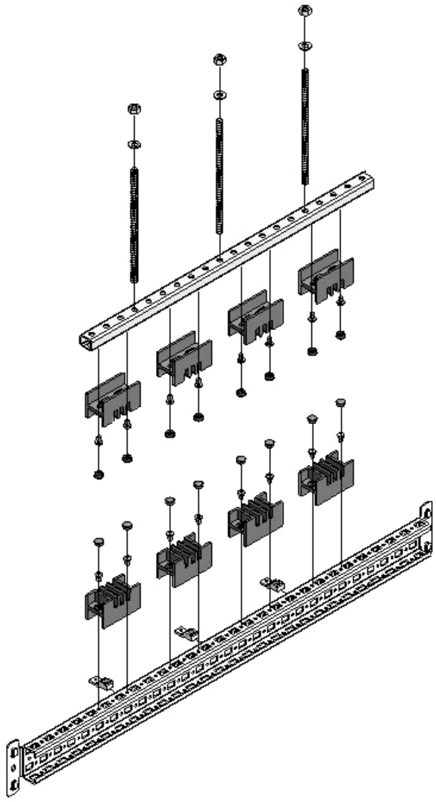




PM MC 0534 T1 A125





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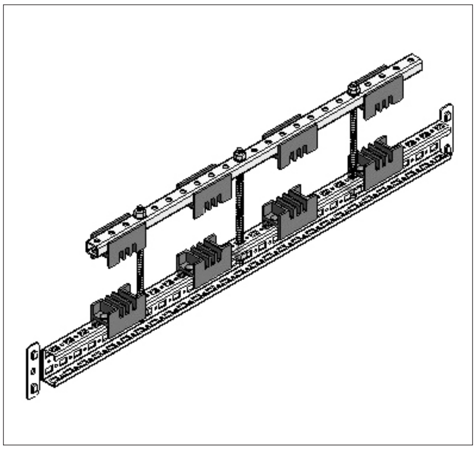

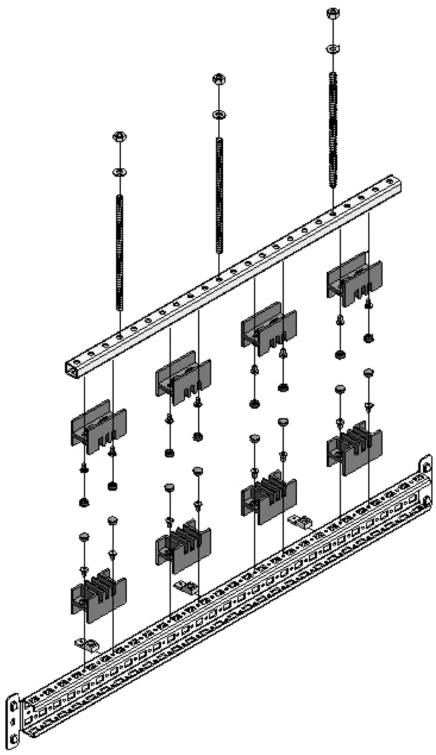

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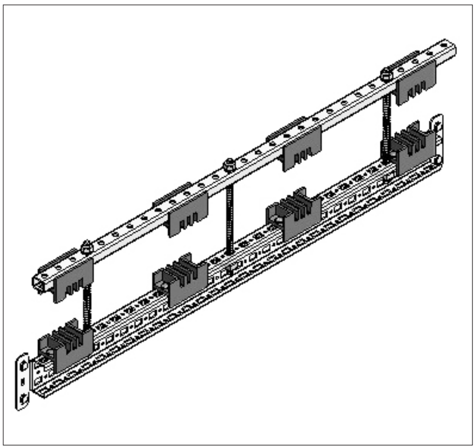

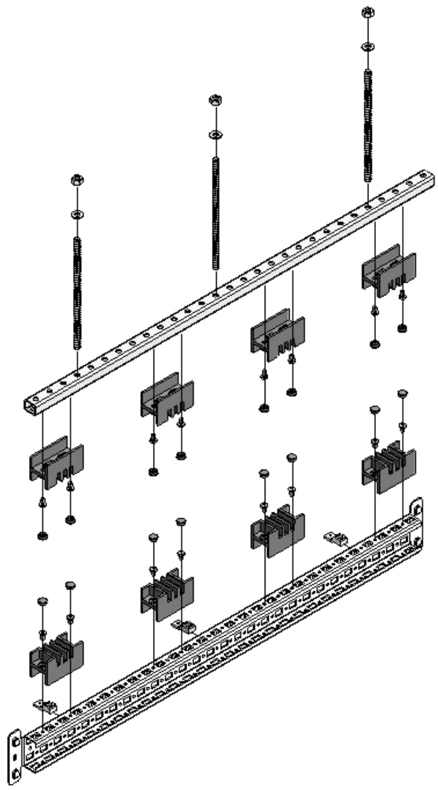

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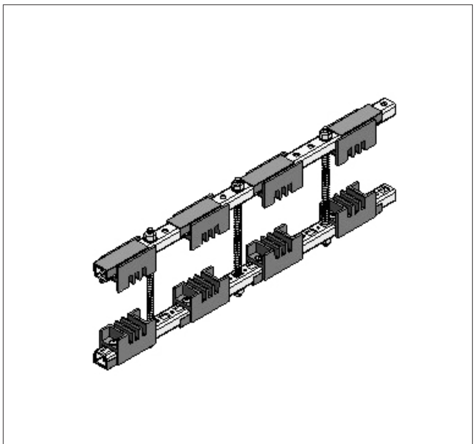

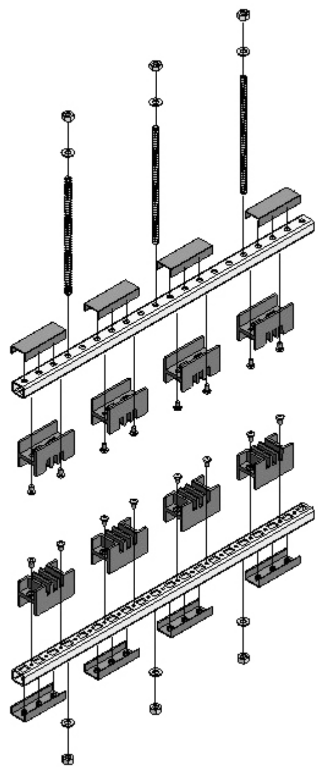

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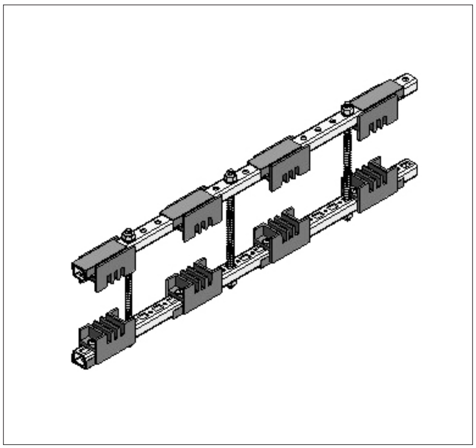
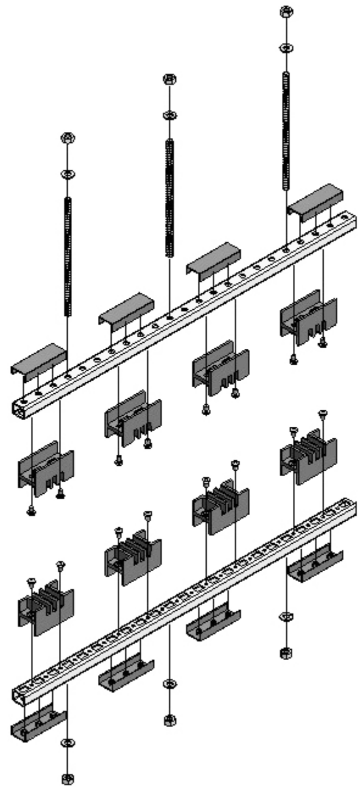
ELEKTROTEKNİK

PM MC 0534 T2 A150





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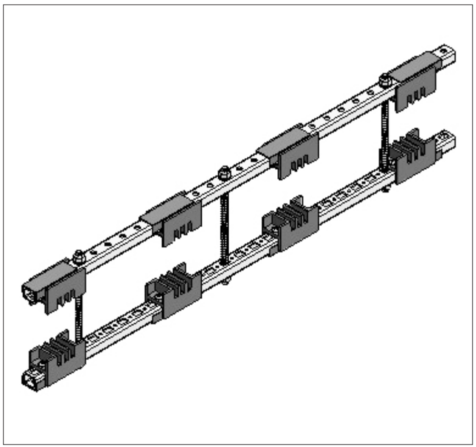
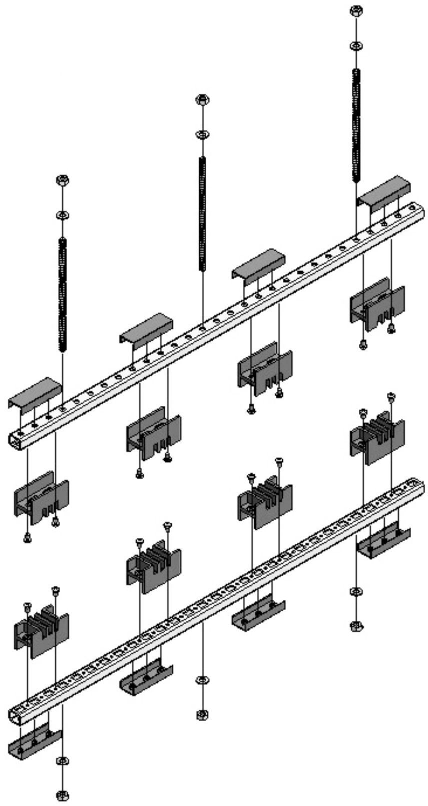
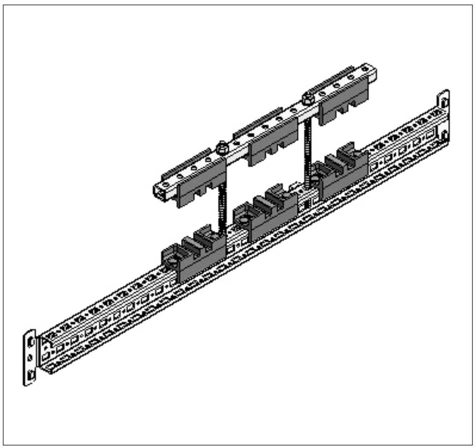
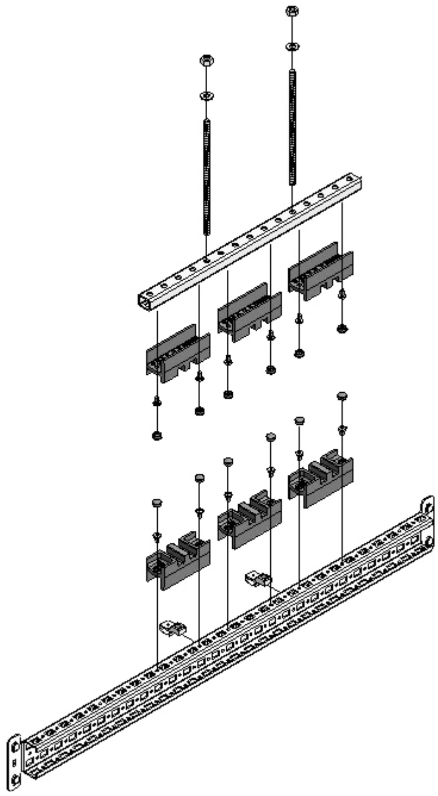




PM MC 1023 T1 A125





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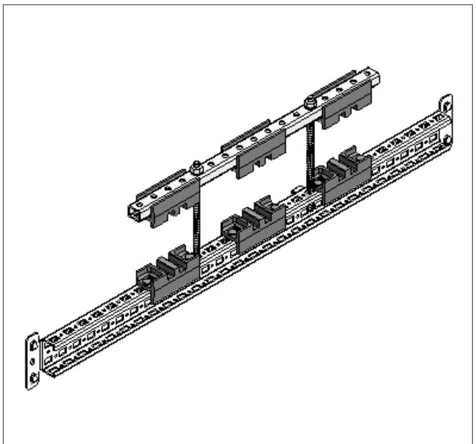

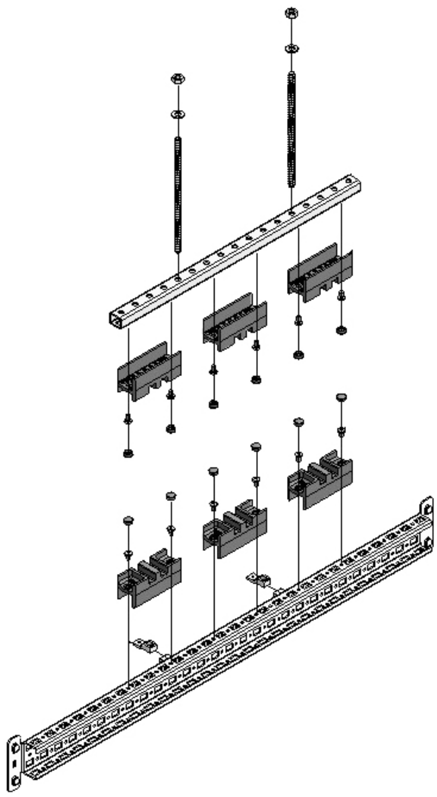

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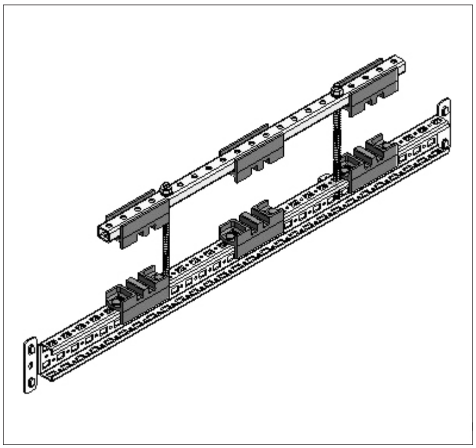

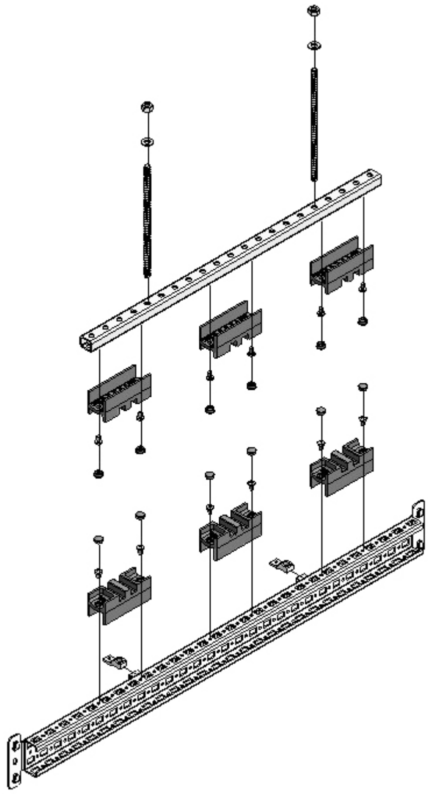

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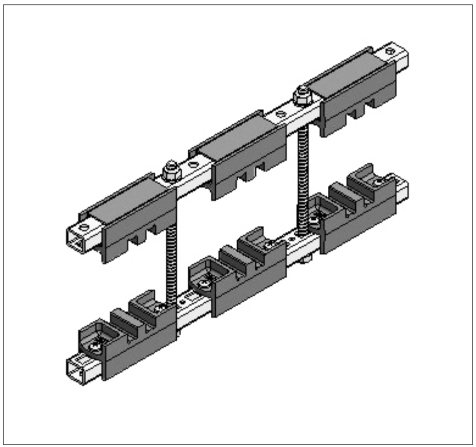

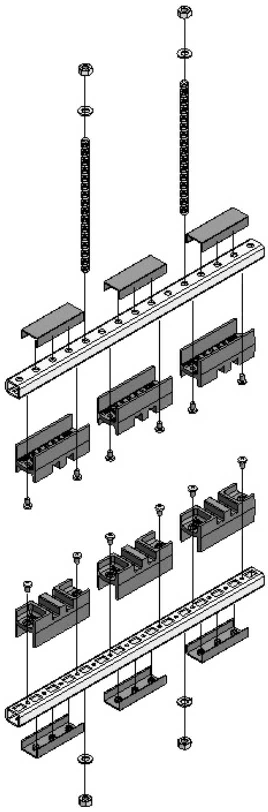

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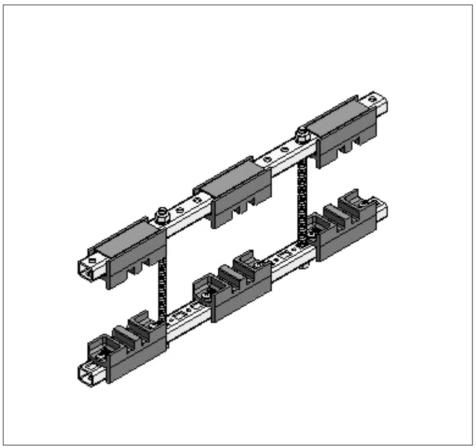

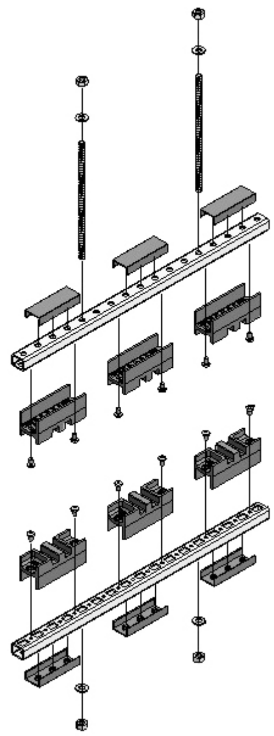

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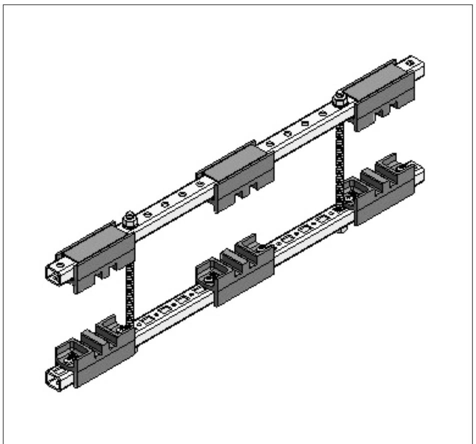

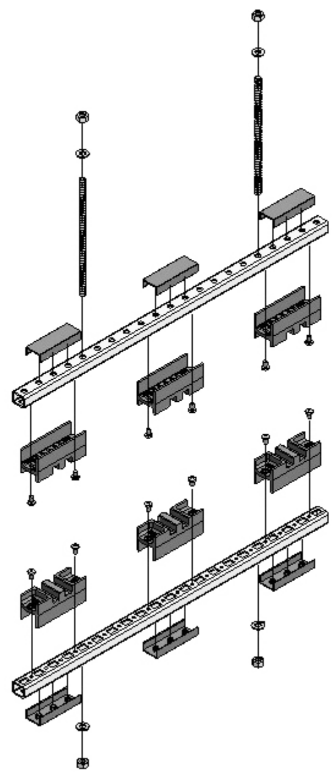

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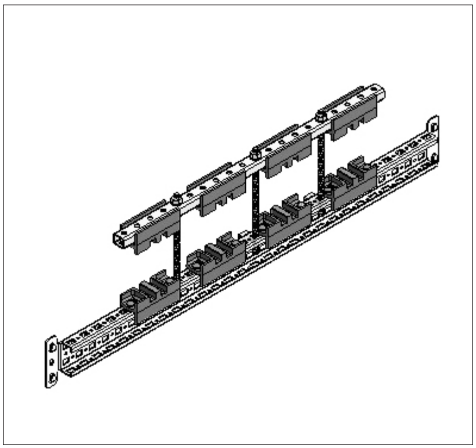

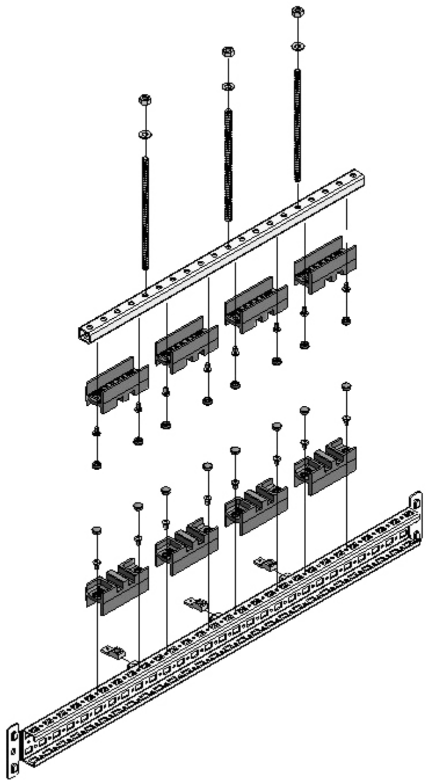

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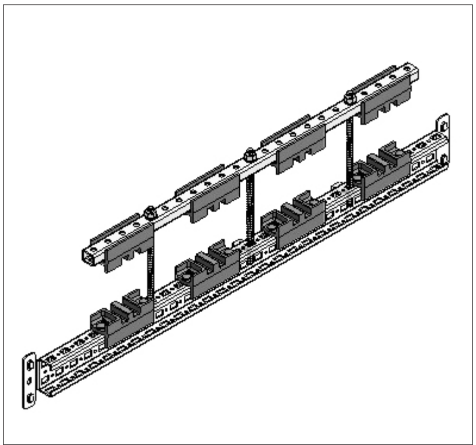

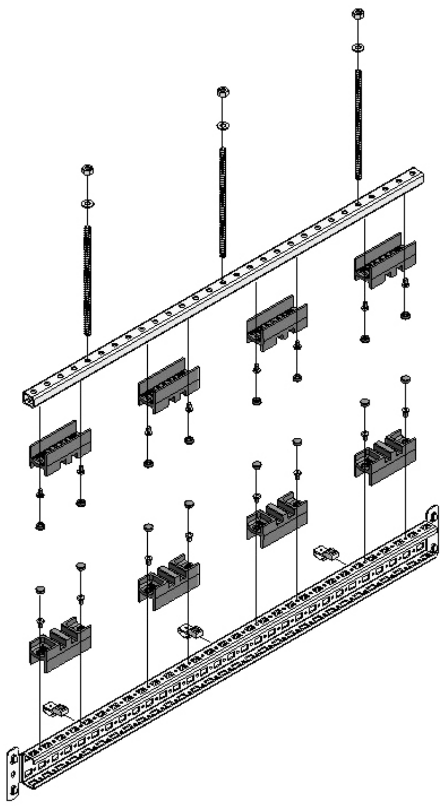

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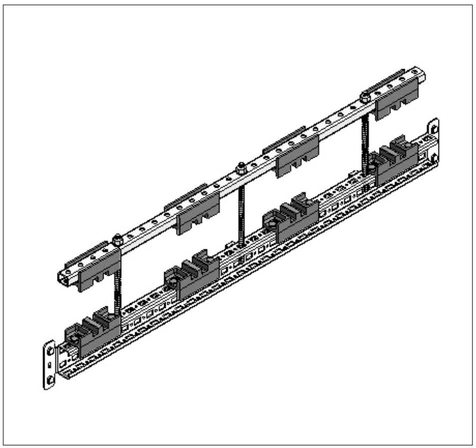

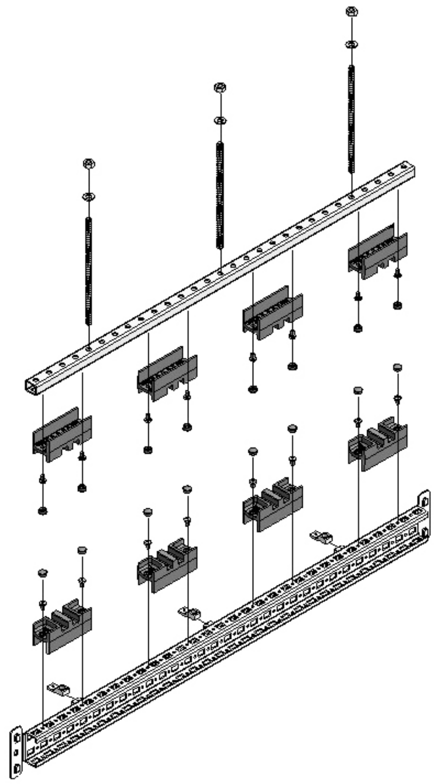

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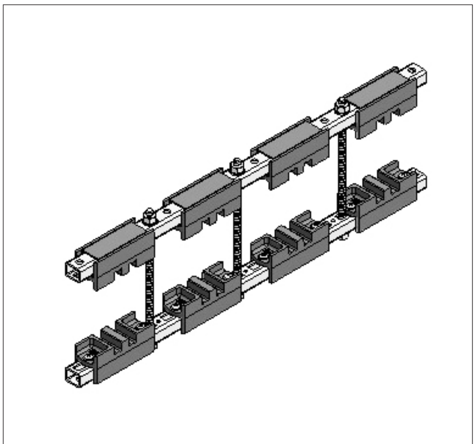

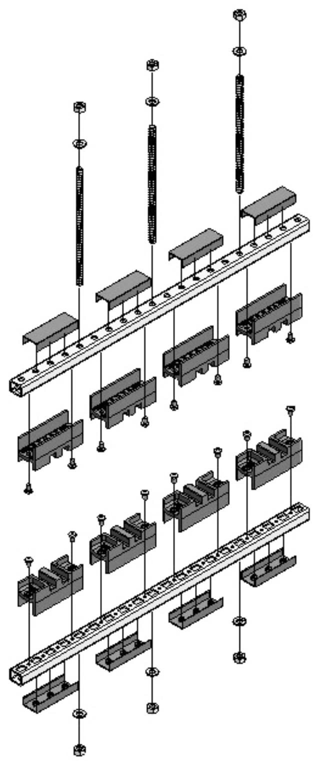

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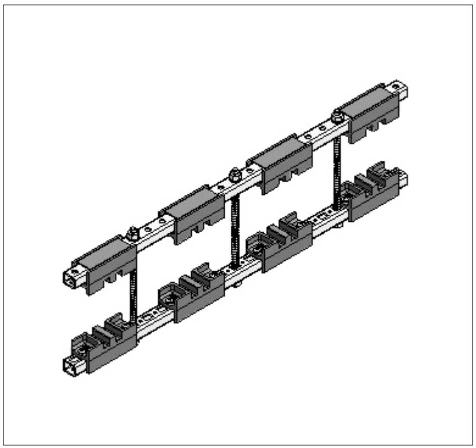

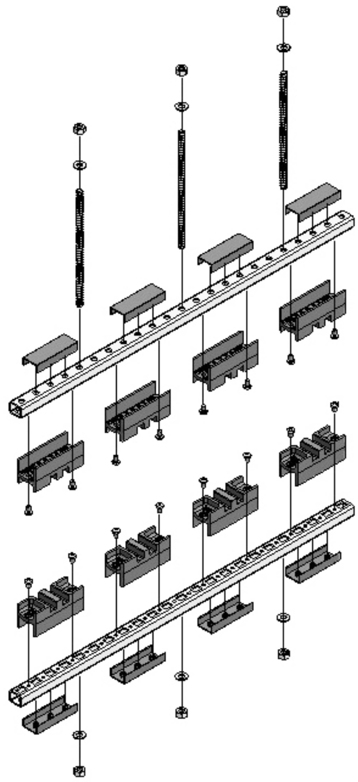

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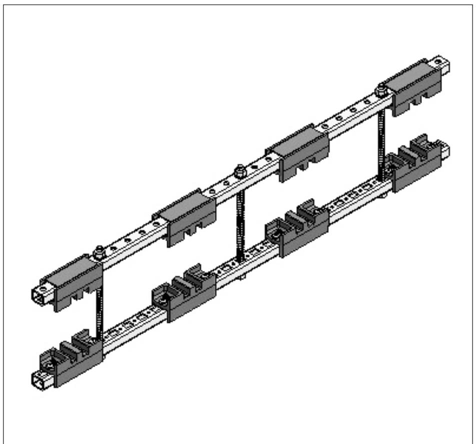

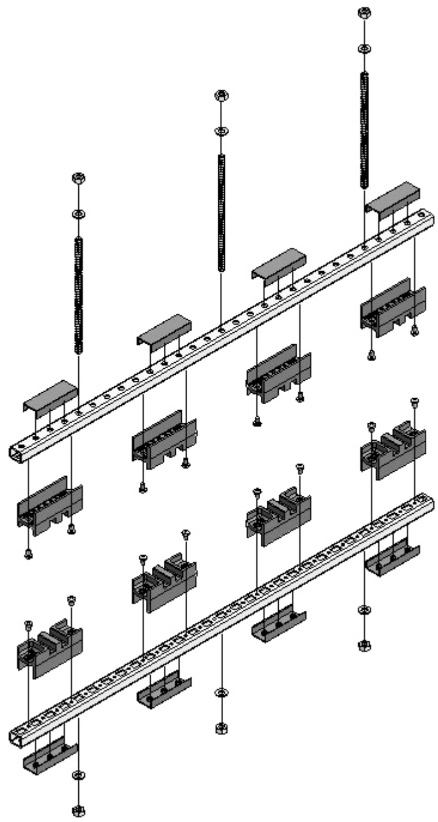

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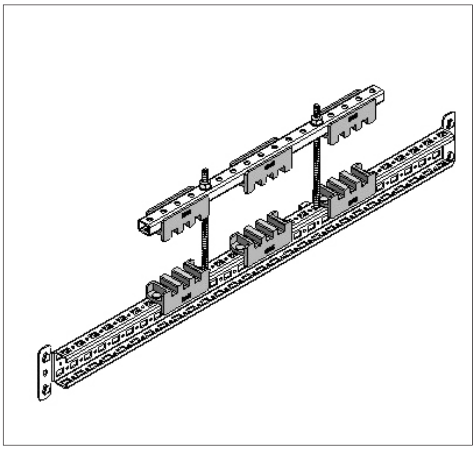

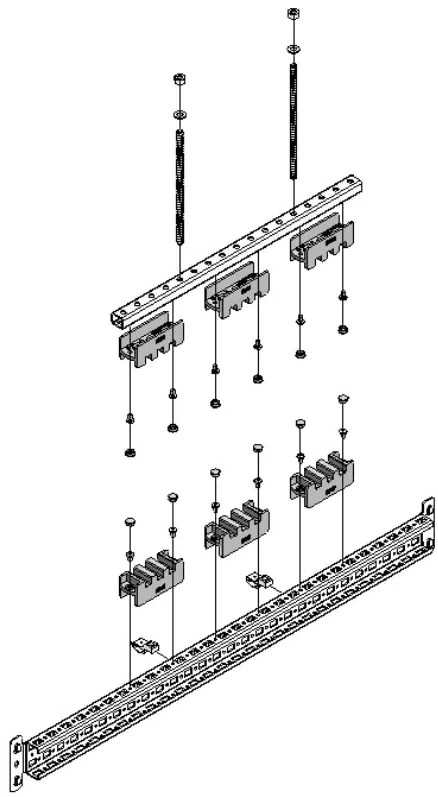

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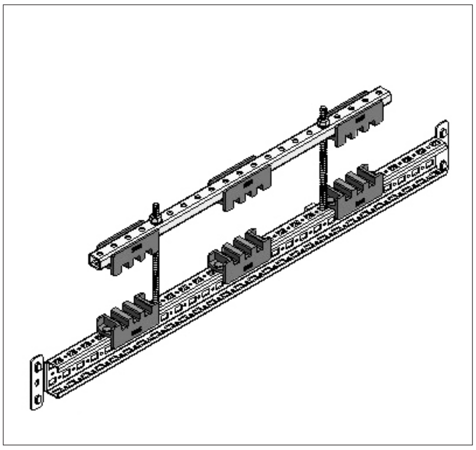

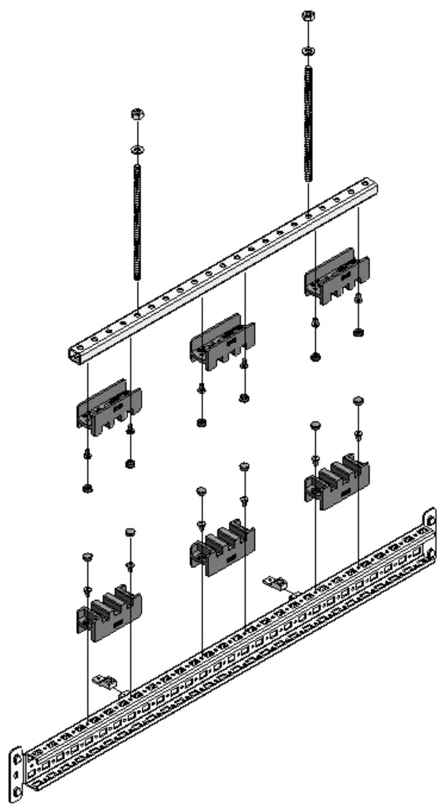

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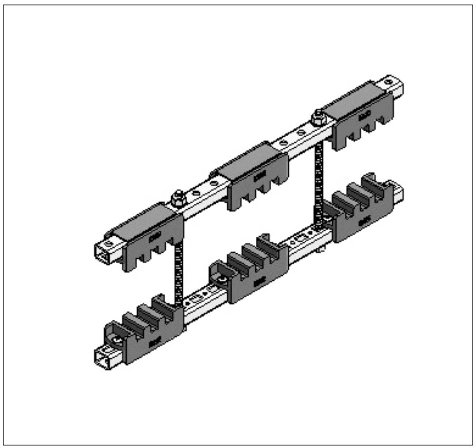

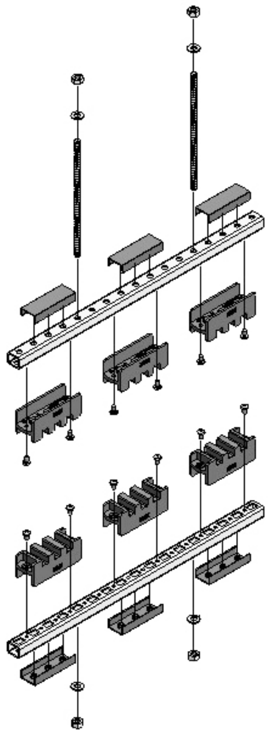

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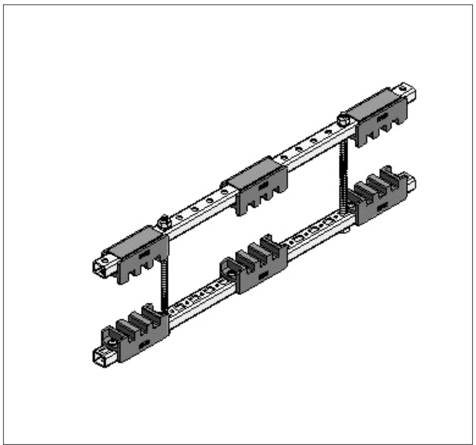

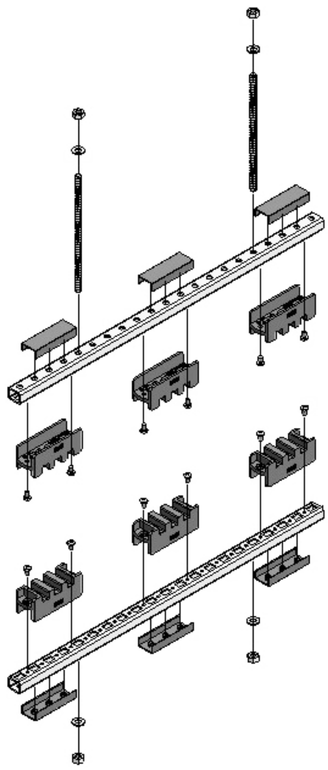

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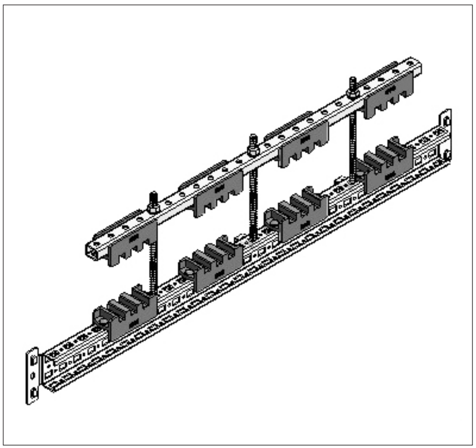

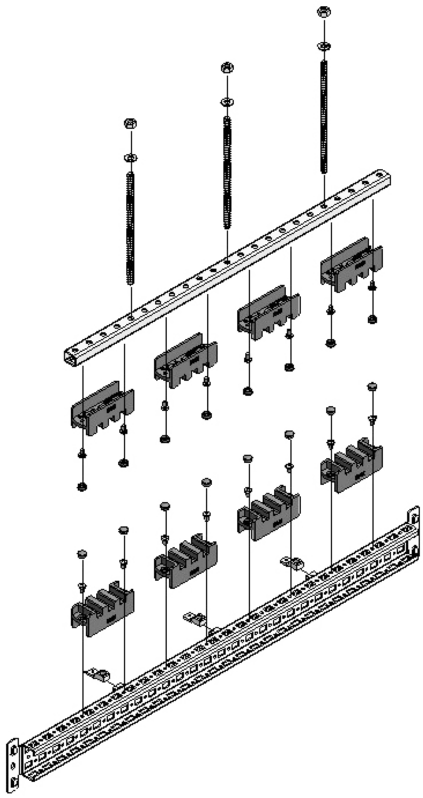

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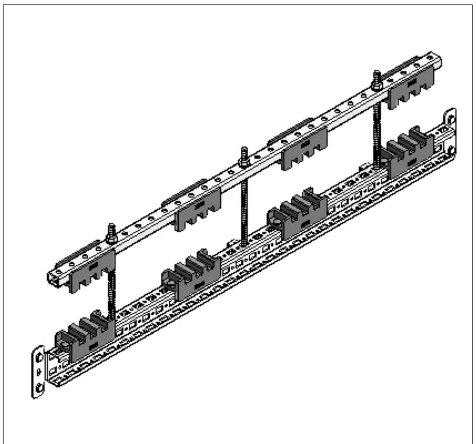

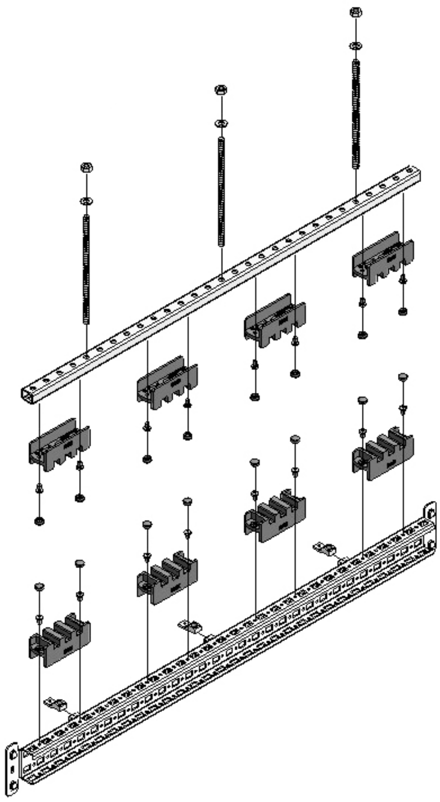

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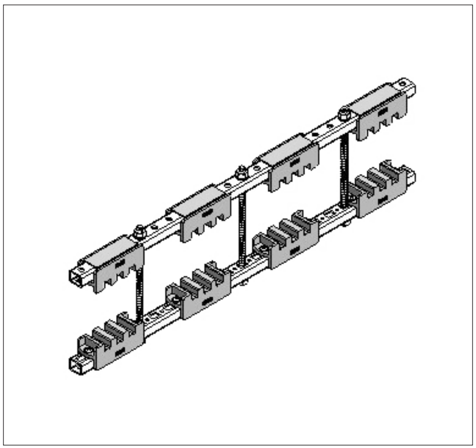

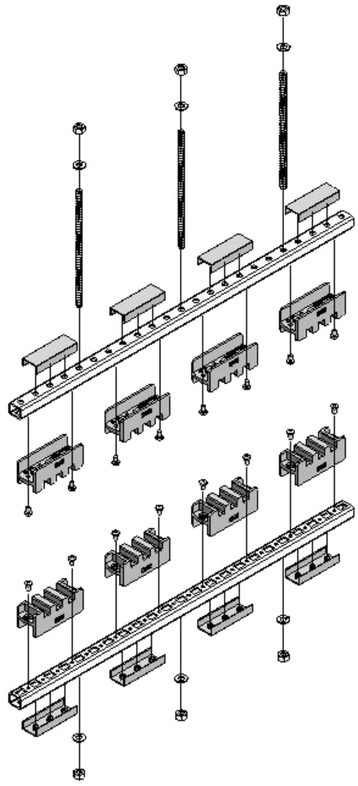

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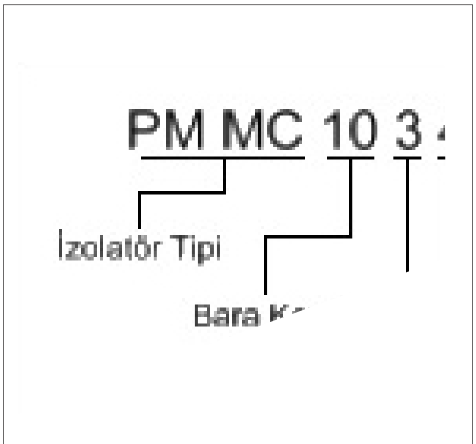
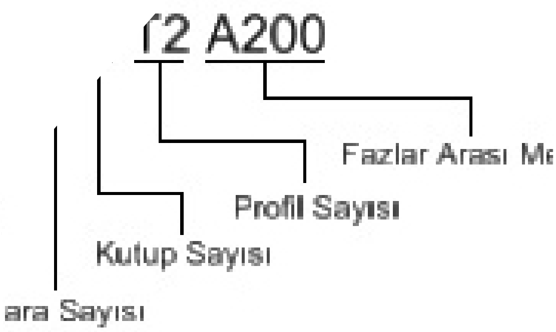


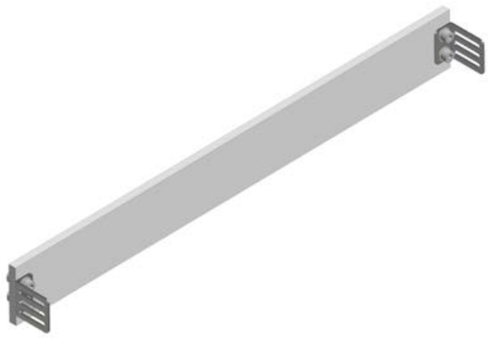


PM GF

Material: glass-fiber reinforced polyester (GRP)

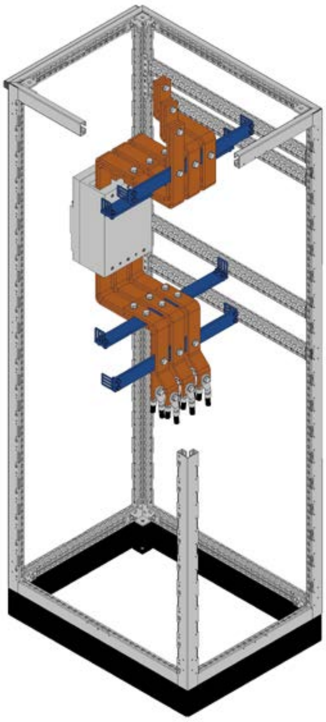
Features:

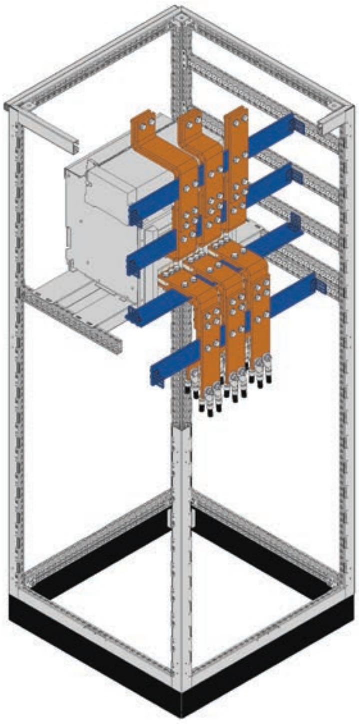
- Halogen-free
- Flame retardant according to UL94 V0
- Maximum effective short circuit current; 100kA
- Maximum operation temperature 120°C



Voltage Insulation Properties:

- Material CTI value; 600V
- Material group; I
- User as indicated IEC 61439-1, defines rated voltage insulation and movement distance -related to application





PM GF Isolator Selection		
Panel Width mm	**GF50**	**GF75**
600	PMGF5006	PMGF7506
700	PMGF5007	PMGF7507
800	PMGF5008	PMGF7508
1000	PMGF5010	PMGF7510
1200	-	PMGF7512
1400	-	PMGF7514

Type test document

76 tests are applied for all insulator types in different phase and support distances.

INSTITUT „PRÜFFELD FÜR ELEKTRISCHE HOCHLEISTUNGSTECHNIK" GMBH — IPH BERLIN

Independent, accredited testing station · Member laboratory of STL and LOVAG

TEST REPORT

NO. 1022.0290.2.174

EAE Elektrik A.S. Ikitelli Organize Sanayi Bölgesi, Turgut Özal Cad. No: 112 TR - 34670 Ikitelli/ISTANBUL	CLIENT
EAE Elektrik A.S. Ikitelli Organize Sanayi Bölgesi,	MANUFACTURER
Insulator systems for low-voltage switchgear assemblies	TEST OBJECT
See Sub-clause 3.1	TYPE
Test sample	MANUFACTURING NO.
Rated operational voltage U_e 1000 V Rated insulation voltage U_i 1000 V Rated frequency 50 Hz Rated peak withstand current I_{pk} See Sub-clause 3.1 Rated short-time withstand current I_{cw} See Sub-clause 3.1	RATED CHARACTERISTICS GIVEN BY THE CLIENT
DIN EN 60439-1(VDE 0660 Teil 500):2000-08 IEC 439-1:1999	NORMATIVE DOCUMENT
Verification of short-circuit withstand strength	RANGE OF TESTS PERFORMED
12 und 13 June 2002	
See Sub-clause 4.6	

H. GLABSCH
Head of high-power test laboratory
Berlin, 23 October 2002

S. GEORGIAS
Test engineer in charge

INSTITUT „PRÜFFELD FÜR ELEKTRISCHE HOCHLEISTUNGSTECHNIK" GMBH — IPH

TEST REPORT NO. 1022.0290.2.174 — SHEET 4

3 Identity of the test object

3.1 Technical data and characteristics

I_{pk} [kA]	$I_{cw,1s}$ [kA]
220	100
220	100
220	100
154	70
220	100
154	70
220	100
264	120
154	70
330	150
220	100
220	100

INSTITUT „PRÜFFELD FÜR ELEKTRISCHE HOCHLEISTUNGSTECHNIK" GMBH — IPH BERLIN

Independent test laboratory, accredited by Deutsche Akkreditierungsstelle Technik (DATech) e.V. in the fields of h.v. apparatus and switchgear, power cables and power cable accessories, l.v. apparatus and switchgear, installation equipment and switching and control equipment

Deutscher Akkreditierungs Rat — DAT - P - 019/92

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E-mail : ekabin@eae.com.tr

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