Co-ordination between device, design current and diversity in assemblies

1. Symbols, terminology and principles

To ensure the correct co-ordination between device(s) and design current(s) in assemblies, it is essential to first understand the symbols and associated terminology.

BS 7671 (IET Wiring Regulations)

I_n rated current or current setting of protective device (A)

Note for adjustable protective devices, the rated current (I_n) is the selected current setting or the installed fuse link rating, according to the design.

I_b design current of circuit (A).

The design current, is the current to be carried by the circuit in normal service. The design current is established by adding the current demand of equipment connected to the circuit and where appropriate making allowances for diversity.

A cyclic load is recognized in regulation 533.2.1 of BS 7671. A cyclic load is a load that is repeated with definable variable currents or 'on' 'off' intervals, e.g. controlled machine process; punching, welding. This provides the opportunity for the current rating of the switching devices, overload protective device and associated cable to be selected on the basis of the design current (I_b) being the thermally equivalent constant load current.

For this the on time has to be relatively short compared with the off time as determined by the duty cycle and the thermal time constant of all the associated devices and the cable. (It should be noted that, BS EN 61439-1 highlights that care should be taken with ON-times greater than 30 min since small devices could already reach the thermal equilibrium). In addition;

(i) care must be exercised to ensure the interaction of devices and similar does not cause issues,
(ii) overcurrent protection does not cause unintentional tripping, and
(iii) that all switching devices are capable of making and breaking the appropriate currents.

To ensure satisfactory performance it is recommended that the on current[1] should not exceed the rated current of the circuit of the assembly.

[1]*In the case of electric motors the on current is normally assumed to be the steady state running current, however, in some instances the starting current and duration may also have to be taken into consideration.*

BS EN 61439 ASSEMBLY (Switchboard, Panel Board, Distribution Board etc.)

I_{nA} rated current of the assembly

I_{nA} is the maximum load current the assembly is designed to manage and distribute. It is the total current which the main busbar is capable of distributing in the particular assembly arrangement. The user should specify the rated current as relevant to their application. The rated current of an incoming circuit may be lower than the rated current of the incoming device (according to the respective device standard) installed in the assembly.

I_{nc} rated current of a circuit (of an assembly)

I_{nc} is the value of current that can be carried by a circuit loaded alone, **i.e. not continuously and simultaneously loaded with other circuits** under normal service conditions. In the absence of any user specification for the rated current of circuits, the manufacturer will state the rated currents of circuits of the assembly within the documentation, taking into consideration the ratings of the devices within the circuit, their disposition and application.

A manufacturer may have to provide a nominally higher rated device in order to achieve a particular rating inside the assembly e.g. the I_n of the device uninstalled may be 250A but when installed in an assembly it may have to be set to 0.8 x 250 A to achieve the desired I_{nc} rating of 200 A. I_n may be any value up to and including I_{nc} and is used in the overload protection co-ordination between conductor and protective device. **I_{nA} and I_{nc} should be provided in the manufacturer's technical documentation supplied with the assembly.**

RDF rated diversity factor (loading factor) for a group of continuously and simultaneously loaded outgoing circuits

RDF is the per unit value of the rated current (loading factor), assigned by the assembly manufacturer, to which a group of outgoing circuits of an assembly can be continuously and simultaneously loaded taking into account the mutual thermal influences.

Rated diversity factor can be stated:

- for groups of circuits;
- for the whole assembly.

The relationship between rated diversity factor and load current should always be accounted for i.e. some circuits will be rated on the basis of being continuously and simultaneously loaded, others will be rated on the basis of inrush currents and intermittent or short duration loads. A number of circuits may be heavily loaded while others are lightly loaded or switched off.

RDF recognizes that multiple functional units are not always, all continually loaded. Guidance as to what does **not** constitute "continually loaded" can be conservatively given for 61439 assemblies as; *"a load not exceeding 30 minutes with a maximum duty cycle of 50 %, unless otherwise specified by the manufacturer"*. This means that the load "off" time must be equal to or greater than its "on" time, with a maximum "on" time of 30 minutes and therefore, diversity need not be applied.

The assumed loading of outgoing circuits is addressed by the relevant assembly standard e.g. part 2, 3, etc. **The RDF for a whole assembly applies to all continuously and simultaneously loaded circuits combined, or a small group. For example, a ten way assembly with a 0.5 RDF, has only four circuits judged to be continuously and simultaneously loaded; unless otherwise specified by the assembly manufacturer,** 0.5 RDF applies to the four circuits.

2. Co-ordination methodology for device and design current in assemblies

BS 7671

BS 7671 requires that the rated current or current setting of the protective device (I_n) is not less than the design current (I_b) of the circuit i.e.

$$I_n \geq I_b$$

Assembly (Switchboard, Panel Board, Distribution Board etc.)

For circuits NOT continuously and simultaneously loaded:

$$I_{nc} \geq I_b$$

For **a group of circuits that are continuously** and **simultaneously loaded,** the rated current of a circuit (I_{nc}) multiplied by the rated diversity factor (RDF) should not be less than the design current (I_b) of the circuit i.e.

$$I_{nc} \times RDF \geq I_b \quad \text{or} \quad I_{nc} \geq I_b / RDF$$

Diversity is not applied to the incoming circuit; the incoming circuit must be capable of operating at its rated current in the assembly I_{nc} with all outgoing functional units collectively loaded to their rated current I_{nc} multiplied by the diversity factor.

For an assembly with a single incoming circuit the rated current of the incoming circuit I_{nc} is its I_{nA}.

3. Diversity factors

Unless otherwise specified by the manufacturer, it is assumed the diversity factor for the assembly is as shown in Table 1 below.

Table 1 - Values of rated diversity (RDF) / assumed loading			
BS EN 61439-2 (typically Switchboards, Panel boards and Motor Control Centres)		BS EN 61439-3 (typically Consumer units and Distribution boards)	
Number of circuits	RDF (assumed loading)	Number of circuits	RDF (assumed loading)
2 and 3	0.9	2 and 3	0.8
4 and 5	0.8	4 and 5	0.7
6 to 9 inclusive	0.7	6 to 9 inclusive	0.6
10 (and above)	0.6	10 (and above)	0.5

The rated RDF is for the number of three-phase ways in a Three Phase & Neutral (TP&N) board and remains the same if single phase circuits are used e.g. a 4 way TP&N board has an RDF of 0.8 and remains 0.8 if 12 single-phase circuits are used.

4. Examples of the co-ordination methodology for device and design current in assemblies

Tables 2 to 4 below provide examples of the co-ordination methodology for device and design current in assemblies:

- Table 2 – Co-ordination between device, design current and diversity in a Switchboard / Panel board
- Table 3 – Co-ordination between device, design current and diversity in a Distribution board
- Table 4 – Co-ordination between device, design current and diversity in a Consumer unit

Table 2 - Co-ordination between device, design current and diversity in a Switchboard / Panel board						
Installation design				**Switchboard / Panel board specification**		
	Circuit description	Design current I_b Amps	Load characteristic C = continuous & simultaneous I = Intermittent	[a]RDF	*Minimum required I_{nc}* *For "C" circuits:* $I_{nc} \geq I_b$ / RDF *For "I" circuits:* $I_{nc} \geq I_b$ Amps	*Rated current of protective device / circuit in the assembly* [b]I_{nc} Amps
1	Machine 1 (L1)	152	C	0.8	190	200
	Machine 1 (L2)	152	C	0.8	190	
	Machine 1 (L3)	152	C	0.8	190	
2	Machine 2 (L1)	15	C	0.8	18.8	25
	Machine 2 (L2)	15	C	0.8	18.8	
	Machine 2 (L3)	15	C	0.8	18.8	
3	Industrial socket (L1)	112.5	I	0.8	[c]112.5	125
	Industrial socket (L2)	112.5	I	0.8	[c]112.5	
	Industrial socket (L3)	112.5	I	0.8	[c]112.5	
4	General sockets (L1)	25.6	I	0.8	[c]25.6	32
	Lighting (L2)	8	C	0.8	10	10
	Lighting (L3)	8	C	0.8	10	10

Minimum rated current of the incoming circuit, main busbars and incoming device (e.g. switch) to supply the connected functional units.

IMPORTANT NOTE: In order to determine the optimum rating of the incoming supply to the assembly (and the assembly), a further allowance for diversity between circuits could be considered. This assessment is particular to the installation and the values chosen are the responsibility of the installation designer. Also, allowances, if any, for spare capacity or load growth must be taken into account.

The marked rated current of the main switch may need to be higher than I_{nA} when installed in the assembly.

I_b Total Amps

L1 305	L2 288	L3 288

I_{nA} (including main switch)

$I_{nA} \geq I_b$ total 400 Amps

Symbol / Abbreviation

I_n rated current or current setting of protective device (A)

I_b design current of circuit (A)

I_{nA} rated current of the Switchboard / Panel board (A)

I_{nc} rated current of the Switchboard / Panel board outgoing circuit (A)

RDF rated diversity factor of the Switchboard / Panel board (assumed loading of outgoing circuits)

Notes

[a] The assembly RDF is assigned by the switchboard / panelboard manufacturer. In this example, the rated RDF is for the number of three-phase ways i.e. a 4 way TP&N board

[b] The rated current or current setting of protective device (I_n) is still used in the overload protection co-ordination between conductor and protective device; in this hypothetical example I_n = 250 A. I_n can be the current setting of protective device e.g. for an adjustable a 250 A circuit-breaker set to 0.8, this would be 200 A.

[c] The installation designer shall determine if it is a continuously and simultaneously loaded circuit. In this example, due to the characteristics of the load, the circuit is deemed **not** to be continuously and simultaneously loaded and therefore, diversity in the assembly does not apply.

Table 3 - Co-ordination between device, design current and diversity in a Distribution board						
Installation design				**Distribution board specification**		
	Circuit description	Design current I_b Amps	Load characteristic C = continuous & simultaneous I = Intermittent	[a]RDF	*Minimum required* I_{nc} *For "C" circuits:* $I_{nc} \geq I_b$ / RDF *For "I" circuits:* $I_{nc} \geq I_b$ Amps	*Rated current of protective device / circuit in the assembly* I_{nc} Amps
1	Shower	46	I	0.7	[b]46	50
2	Cooker	26	I	0.7	[b]26	32
3	External lighting dusk-dawn	5	C	0.7	7.1	10
4	Internal lighting	4.5	C	0.7	6.4	10
I_b total Amps Minimum rated current of the incoming circuit, main busbars and incoming device (e.g. switch) to supply the connected functional units. IMPORTANT NOTE: In order to determine the optimum rating of the incoming supply to the assembly (and the assembly), a further allowance for diversity between circuits could be considered. This assessment is particular to the installation and the values chosen are the responsibility of the installation designer. Also, allowances, if any, for spare capacity or load growth must be taken into account.				**81.5**	Symbol / Abbreviation I_n rated current of protective device (A) I_b design current of circuit (A) I_{nA} rated current of the Distribution board (A) I_{nc} rated current of the Distribution board outgoing circuit (A) RDF rated diversity factor of the Distribution board (assumed loading of outgoing circuits)	
I_{nA} (A) (including the main switch within the assembly) **$I_{nA} \geq I_b$ total** The marked rated current of the main switch may need to be higher than I_{nA} when installed in the assembly.				**100**		

Notes

[a] The assembly RDF is assigned by the distribution board manufacturer. In this example, the rated RDF is for the number of single-phase ways i.e. a 4 way distribution board.

[b] The installation designer shall determine if it is a continuously and simultaneously loaded circuit. In this example, due to the characteristics of the load, the circuit is deemed not to be continuously and simultaneously loaded.

Table 4 - Co-ordination between device, design current and diversity in a Consumer unit						
Installation design				**Consumer unite specification**		
	Circuit description	Design current I_b Amps	Load characteristic C = continuous & simultaneous I = Intermittent	[a]RDF	*Minimum required I_{nc}* *For "C" circuits:* $I_{nc} \geq I_b$ / RDF *For "I" circuits:* $I_{nc} \geq I_b$ Amps	*Rated current of protective device / circuit in the assembly* I_{nc} Amps
1	Storage heater	13	C	0.7	18.6	20
2	Storage heater	13	C	0.7	18.6	20
3	Storage heater	13	C	0.7	18.6	20
4	Storage heater	13	C	0.7	18.6	20
I_b total Amps Minimum rated current of the incoming circuit, main busbars and incoming device (e.g. switch) to supply the connected functional units. No further allowance for diversity between circuits can be considered as all circuits are likely to be loaded at the same time. **Allowances, if any, for spare capacity or load growth must be taken into account.**				52	Symbol / Abbreviation I_n rated current of protective device (A) I_b design current of circuit (A) I_{nA} rated current of the Consumer unit (A) I_{nc} rated current of the Consumer unit outgoing circuit (A) RDF rated diversity factor of the Consumer unit (assumed loading of outgoing circuits)	
Consumer unit I_{nA} (A) (including the main switch within the consumer unit) $I_{nA} \geq I_b$ total The marked rated current of the main switch may need to be higher than I_{nA} when installed in the assembly.				63		
Notes [a] The assembly RDF is assigned by the consumer unit manufacturer. In this example, the rated RDF is for the number of single-phase ways i.e. a 4 way consumer unit.						

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