Co-ordination between circuit protective devices
The proper co-ordination of two circuit protective devices is essential in all installations in order to fulfil the requirements of the Wiring Regulations which set out to ensure the safe continuity of supply of electrical current under all conditions of service. If a fault does occur, the circuit protective device nearest the fault should operate, allowing the device immediately upstream to continue to supply healthy circuits. This is called discrimination.

Sometimes the upstream device is selected to protect the downstream device(s) against high prospective short circuit currents and will operate to provide this protection should the actual short circuit current rise to a level which cannot be handled by the device nearest the fault. This is called back-up protection and devices should be so chosen as to allow discrimination up to the point the back-up device takes over.

Discrimination
Discrimination, which is sometimes called selectivity, is the co-ordination of two automatic circuit protective devices in such a way that a fault appearing at any given point in an installation is cleared by the protective device installed immediately upstream of the fault and by that device alone.

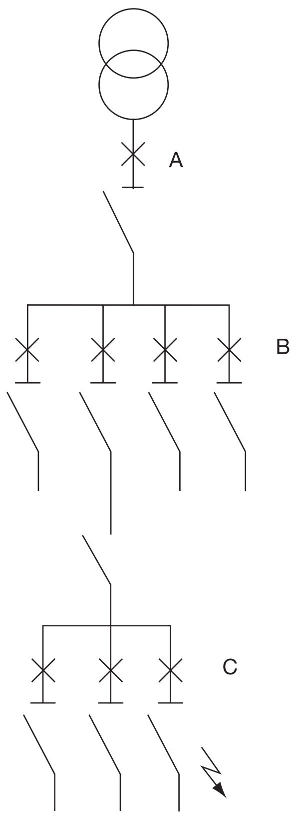


Fig 22

Example
A fault occurs downstream of final sub-circuit device “C”. All other protective devices remain closed ensuring continuity of supply to the rest of the installation.

When this ideal situation is achieved under all conditions it is called “total discrimination”.

Discrimination between two protective devices can be based on either the magnitude of the fault which is called “current discrimination” or the duration of the time the upstream device can withstand the fault current; this is called “time discrimination”.

Current discrimination
In order to achieve “current discrimination” in a distribution system it is necessary for the downstream device to have a lower continuous current rating and a lower instantaneous tripping value than the upstream device. Current discrimination increases as the difference between the continuous current ratings of the upstream and downstream devices increases.

A simple way of checking current discrimination at both overload and short-circuit conditions is to compare the time/current characteristic curves of both devices plotted to the same scale. Transparency overlays, if available, make this task much easier (see Fig 23). For this example the time/current characteristics of a 32A type ‘B’ circuit breaker complying with EN 60898, with a 100A category ‘A’ circuit breaker to EN 60947-2 are checked for current discrimination.

Because the thermal characteristic curve of the upstream circuit breaker clears the knee of the characteristic curve of the smaller downstream breaker, it can be said that overload discrimination is achieved under all conditions. However because the instantaneous characteristic curves cross at 0.01 sec, short-circuit discrimination is limited up to the point they cross, which in this case is approximately 2.7kA. The point at which the two time / current characteristics cross is called the limit of discrimination or selectivity. In this example the level of discrimination Is is 2.7kA, so we only have partial discrimination between these two devices.

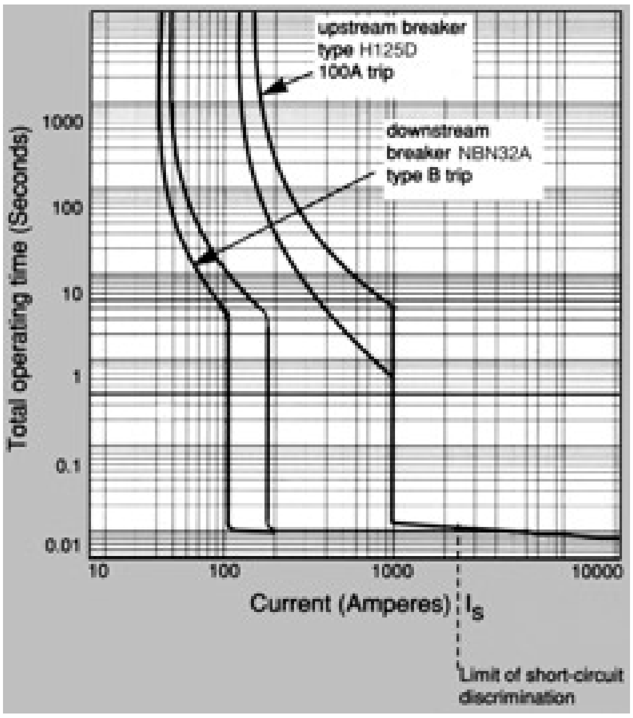


Fig 23

Time discrimination
Time discrimination is achieved by delaying the opening of the upstream circuit breaker until the downstream circuit breaker haopened and cleared the fault. The total clearing time of the downstream circuit breaker must be less than the time setting of the upstream circuit breaker and the upstream circuit breaker must be able to withstand the fault current for the time setting period. Therefore the upstream circuit breaker must be a category 'B' breaker which has been designed and tested for this purpose.

To determine time discrimination it is only necessary to compare the time/current characteristic curves of the two devices to ensure that no overlap occurs.

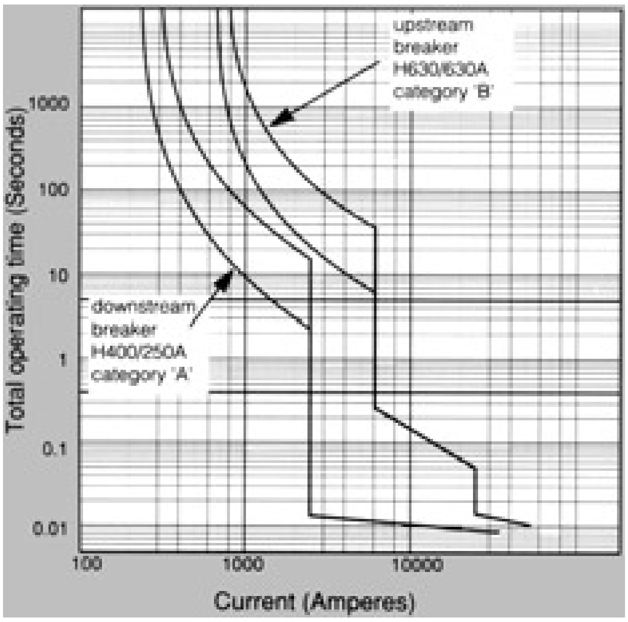


Fig 24

Short circuit discrimination
A more accurate way of checking the discrimination between two circuit protective devices at short circuit levels is to compare the energy let-through of the downstream device with the no-tripping or pre-arcing energy levels of the upstream device.

In order to check current discrimination at short circuit levels between:
Fuse upstream - fuse downstream
It is only necessary to compare the I^2t values of each fuse. This information is usually available in very simple tabular form (see Table 33). If the total let-through energy (I^2t) of the downstream fuse is less than the pre-arcing energy (I^2t) of the upstream fuse, then total discrimination is achieved at short-circuit levels.

Fuse I²t characteristics

Rated current Amperes	Pre-arching I²t kA2s	Total I²t kA2s
6	0.01	0.025
10	0.07	0.25
16	0.17	0.45
20	0.31	0.90
25	0.62	1.90
32	1.00	3.0
40	2.1	8.0
50	7.0	17
63	11	30
80	22	70
100	39	100
125	62	170
160	101	300
200	190	500
315	480	1100
400	800	2100
500	1100	3100
630	1800	5000

Table 33

MCB Total let-through energy

MCB In	Total let-through energy kA2S at PSCC 3kA	6kA	10kA
6	5.9	10.5	15
10	6.5	12.2	21.5
16	8.0	17.5	30
20	8.8	19.5	34
25	10	21	38
32	11	24	42
40	12.5	29	50
50	15	34	61
63	16	38	72

Table 34

Fuse upstream - Circuit breaker downstream. The same procedure applies to fuse/circuit breaker as it does to fuse/fuse association to check current discrimination.

While for all practical purposes, a desk top study of time/current and let-through energy (I2t) characteristics are perfectly adequate, the European Standards for circuit breakers do recommend testing to confirm the results. With this in mind Hager have prepared a complete list of discrimination levels for all its circuit protective devices.

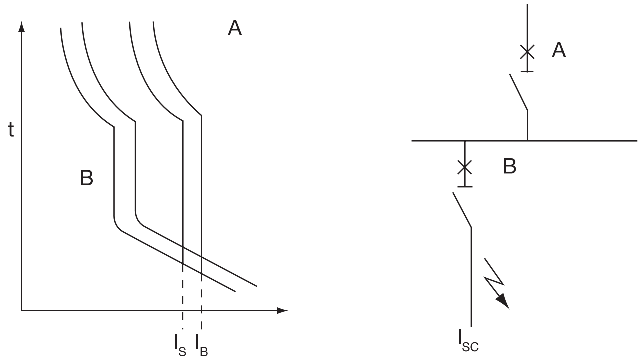
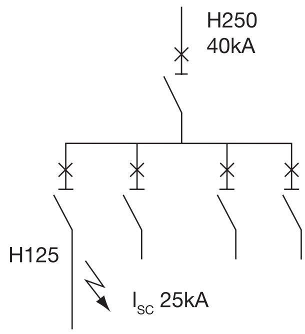


Fig 25 Back-up protection co-ordination



Back-up protection

Sometimes known as cascading, when the energy limiting capacity of an upstream breaker is used to allow the use of a downstream circuit breaker having a short circuit breaking capacity (I_{cu}) lower than the prospective fault level at the point at which it is installed. Table 35 shows the prospective fault level achieved with cascading.

It should be noted that when two circuit protective devices are used in association to improve the short-circuit capacity of the downstream device, total selectivity can never be achieved up to the assigned breaking capacity of the association.

The upstream device must at some point operate to provide the necessary protection to the downstream circuit breaker. This point, which is known as the take-over current, must not be greater than the rated short-circuit capacity of the downstream circuit breaker alone. It therefore follows that the limit of selectivity Is will be less than the take-over current IB . See Fig 25.

Example

A panelboard is to be installed at a point where the prospective fault level is 25kA. 250A incoming and 16A TP outgoing circuits. Select the lowest cost circuit breakers which may be used. See Fig 26.

Incoming - Hager H250 MCCB having an I_{cu} of 40kA.

From Table 35 we see we can select a Hager H125 MCCB having an I_{cu} of 16kA to EN60947-2 but enhanced to 30kA with cascading.

Co-ordination

Definition
This allows circuit breakers of lower breaking capacity than the PSCC to be installed. The principle is that two breakers operating in series will clear a larger fault and that energy let through by the upstream breaker will not damage the down stream device.

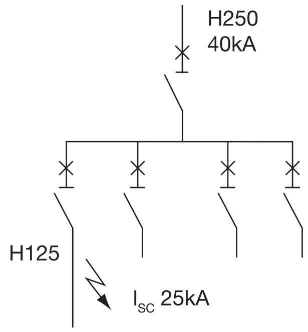


Fig 27

Circuit breaker to circuit breaker back-up protection

Upstream device	125A Frame MCCB	250A Frame MCCB	400A Frame MCCB	630A Frame MCCB	800A Frame MCCB
Downstream Device					
6kA MCBs MTN	16	20			
10kA MCBs NBN, NCN, NDN	16	20			
125A frame MCCB		30	30	30	30
250A frame device			45	50	50
400A frame device				50	50
630A frame device					

☐ Please consult us

Table 35

Fuse to MCCB back-up protection

Upstream							
Downstream	**Device type**	**BS88 Gg 250A**	**BS88 Gg 315A**	**BS88 Gg 400A**	**BS88 Gg 630A**	**BS88 Gg 800A**	**BS88 Gg 1000A**
	125A frame	80kA					
	160A frame		80kA	80kA			
	250A frame			80kA	80kA		
	400A frame				80kA	80kA	
	630A frame						80kA

Table 36

Prospective fault levels to which selectivity is achieved.

	NCN									**NDN**								
EN 947-2	**10kA**				**15kA**									**10kA**				
Curve					**C**									**D**				
In	6A	10A	16A	20A	25A	32A	40A	50A	63A	6A	10A	16A	20A	25A	32A	40A	50A	63A
MTN/NB																		
6A			0.12	0.15	0.19	0.24	0.3	0.38	0.47		0.15	0.24	0.3	0.38	0.48	0.6	0.75	0.95
10A				0.15	0.19	0.24	0.3	0.38	0.47			0.24	0.3	0.38	0.48	0.6	0.75	0.95
16A					0.19	0.24	0.3	0.38	0.47					0.38	0.48	0.6	0.75	0.95
20A						0.24	0.3	0.38	0.47						0.48	0.6	0.75	0.95
25A							0.3	0.38	0.47							0.6	0.75	0.95
32A								0.38	0.47								0.75	0.95
40A									0.47									0.95
NC																		
0.5A	0.05	0.08	0.12	0.15	0.19	0.24	0.3	0.38	0.47	0.09	0.15	0.24	0.3	0.38	0.48	0.6	0.75	0.95
1A	0.05	0.08	0.12	0.15	0.19	0.24	0.3	0.38	0.47	0.09	0.15	0.24	0.3	0.38	0.48	0.6	0.75	0.95
2A	0.05	0.08	0.12	0.15	0.19	0.24	0.3	0.38	0.47	0.09	0.15	0.24	0.3	0.38	0.48	0.6	0.75	0.95
3A	0.05	0.08	0.12	0.15	0.19	0.24	0.3	0.38	0.47	0.09	0.15	0.24	0.3	0.38	0.48	0.6	0.75	0.95
4A		0.08	0.12	0.15	0.19	0.24	0.3	0.38	0.47	0.09	0.15	0.24	0.3	0.38	0.48	0.6	0.75	0.95
6A			0.12	0.15	0.19	0.24	0.3	0.38	0.47		0.15	0.24	0.3	0.38	0.48	0.6	0.75	0.95
10A				0.15	0.19	0.24	0.3	0.38	0.47			0.24	0.3	0.38	0.48	0.6	0.75	0.95
16A					0.19	0.24	0.3	0.38	0.47					0.38	0.48	0.6	0.75	0.95
20A						0.24	0.3	0.38	0.47						0.48	0.6	0.75	0.95
25A							0.3	0.38	0.47							0.6	0.75	0.95
32A								0.38	0.47								0.75	0.95
40A									0.47									0.95
ND																		
6A				0.15	0.19	0.24	0.3	0.38	0.47			0.24	0.3	0.38	0.48	0.6	0.75	0.95
10A						0.24	0.3	0.38	0.47					0.38	0.48	0.6	0.75	0.95
16A								0.38	0.47						0.48	0.6	0.75	0.95
20A									0.47							0.6	0.75	0.95
25A																	0.75	0.95
32A																		0.95

Table 37

Circuit breaker discrimination chart - fuse/MCCB to MCB

			BS 88			HM	H125D										H250			H400		H630 to H800		
IEC 947-2			80kA			10kA	16kA										35kA			45/50kA				
curve			Gg1			C																		
In	40	50	63	80	100	80/100/125	16	20	25	32	40	50	63	80	100	125	160	200	250	320	400	500	630	800
MBN/NBN																								
6A	3.4	3.8	T	T	T	0.6	1.3	1.4	1.6	1.9	2.3	2.9	4	5.5	6.7	8.6	T	T	T	T	T	T	T	T
10A	2	2.5	4	6	T	0.6	1.1	1.2	1.4	1.7	2	2.4	2.8	3.4	4	4.9	T	T	T	T	T	T	T	T
16A	1.2	2	3	5	8	0.6			1.3	1.5	1.8	2.1	2.4	2.8	3.2	3.7	9.5	T	T	T	T	T	T	T
20A	1	1.5	3	4.5	7	0.6				1.5	1.8	2.1	2.4	2.8	3.2	3.7	9.5	T	T	T	T	T	T	T
25A	1	1.3	2.6	3.5	6	0.6					1.7	1.9	2.1	2.3	2.5	2.9	6.2	T	T	T	T	T	T	T
32A		1.2	2.1	2.8	4.2	0.6						1.9	2.1	2.3	2.5	2.9	6.2	T	T	T	T	T	T	T
40A			2	2.6	3.5	0.6							1.6	1.7	1.9	2.2	5	8.1	T	T	T	T	T	T
50A				3	3	0.6								1.4	1.5	1.8	4.1	6.8	T	T	T	T	T	T
63A					2.5										1.2	1.4	3.3	5.9	9.4	T	T	T	T	T
NCN																								
0.5A	T	T	T	T	T	0.6	1.3	1.4	1.6	1.9	2.4	3.7	5.6	8.8	T	T	T	T	T	T	T	T	T	T
1A	T	T	T	T	T	0.6	1.3	1.4	1.6	1.9	2.4	3.7	5.6	8.8	T	T	T	T	T	T	T	T	T	T
2A	T	T	T	T	T	0.6	1.3	1.4	1.6	1.9	2.4	3.7	5.6	8.8	T	T	T	T	T	T	T	T	T	T
3A	6	6	T	T	T	0.6	1.1	1.2	1.4	1.7	2	2.5	3.4	4.8	5.8	6.7	T	T	T	T	T	T	T	T
4A	4.5	4.5	T	T	T	0.6	1.1	1.2	1.4	1.7	2	2.5	3.4	4.8	5.8	6.7	T	T	T	T	T	T	T	T
6A	3.4	3.8	T	T	T	0.6	1.1	1.2	1.4	1.7	2	2.5	3.4	4.8	5.8	6.7	T	T	T	T	T	T	T	T
10A	2	2.5	4	6	T	0.6		1.1	1.2	1.4	1.7	2.1	2.5	3	3.5	4.3	T	T	T	T	T	T	T	T
16A	1.2	2	3	5	8	0.6				1.3	1.6	1.9	2.1	2.4	2.7	3.2	8.3	T	T	T	T	T	T	T
20A	1	1.5	3	4.5	7	0.6					1.6	1.9	2.1	2.4	2.7	3.2	8.3	T	T	T	T	T	T	T
25A	1	1.3	2.6	3.5	6	0.6						1.7	1.8	2	2.2	2.5	5.4	8.7	T	T	T	T	T	T
32A		1.2	2.1	2.6	4.2	0.6							1.8	2	2.2	2.5	5.4	8.7	T	T	T	T	T	T
40A			2	2.6	3.5	0.6								1.5	1.7	2	4.3	7	T	T	T	T	T	T
50A				3	3	0.6									1.3	1.5	3.6	5.9	9	T	T	T	T	T
63A					2.5											1.1	2.8	5.2	8.2	T	T	T	T	T
NDN																								
6A	3.4	3.8	T	T	T	0.6	0.9	1	1.1	1.3	1.6	2	2.7	3.8	4.7	5.3	T	T	T	T	T	T	T	T
10A	2	2.5	4	6	T	0.6			0.95	1.1	1.4	1.7	2	2.4	2.8	3.4	8.3	T	T	T	T	T	T	T
16A	1.2	2	3	5	8	0.6					1.3	1.5	1.7	1.9	2.2	2.6	6.7	T	T	T	T	T	T	T
20A	1	1.5	3	4.5	7	0.6						1.5	1.7	1.9	2.2	2.6	6.7	T	T	T	T	T	T	T
25A	1	1.3	2.6	3.5	6	0.6							1.4	1.6	1.7	2	4.3	6.9	T	T	T	T	T	T
32A		1.2	2.1	2.8	4.2	0.6								1.6	1.7	2	4.3	6.9	T	T	T	T	T	T
40A			2	2.6	3.5	0.6									1.3	1.5	3.4	5.6	8.4	T	T	T	T	T
50A				3	3	0.6										1.2	2.9	4.7	7.1	T	T	T	T	T
63A					2.5												2.2	4.2	6.6	T	T	T	T	T
HM																								
80A																	1.7	3.9	6.6	T	T	T	T	T
100A																	1.7	3.9	6.6	T	T	T	T	T

Table 38

Protection

MCCB to MCCB

		H125										**H250**			**H400**			**H630 / H800**			
In	A	16	20	25	32	40	50	63	80	100	125	160	200	250	250	320	400	400	500	630	800
H125	16			0.9	1	1	1	0.95	1	1.1	1.3	1.6	2	2.5	2.3	3	3.4	5.6	6.4	8.3	8.3
	20				1	1	1	0.95	1	1.1	1.3	1.6	2	2.5	2.3	3	3.4	5.6	6.4	8.3	8.3
	25					1	1	0.95	1	1.1	1.3	1.6	2	2.5	2.3	3	3.4	5.6	6.4	8.3	8.3
	32						1	0.95	1	1.1	1.3	1.6	2	2.5	2.3	3	3.4	5.6	6.4	8.3	8.3
	40							0.95	1	1.1	1.3	1.6	2	2.5	2.3	3	3.4	5.6	6.4	8.3	8.3
	50								1	1.1	1.3	1.6	2	2.5	2.3	3	3.4	5.6	6.4	8.3	8.3
	63									1.1	1.3	1.6	2	2.5	2.1	2.5	3.4	5.6	6.4	8	8
	80										1.3	1.6	2	2.5	2	2.5	3.4	5.6	6.4	8	8
	100											1.6	2	2.5	2	2.5	3.4	5.6	6	8	8
	125												2	2.5	2	2.5	3.4	5.6	6	8	8
H250	160													2.5	2	2.5	3.4	4	4	4.5	4.5
	200															2.4	3.4	4	4	4.5	4.5
	250															2.4	3.4	4	4	4.5	4.5
H400	250															2.4	3.4	4	4	4	4
	320																3.4	4	4	4	4
	400																			4	4
H630	400																			4.4	4.4
	500																				
	630																				
	800																				

Table 39

Circuit Breaker Z_L Values & Energy Let Through

Earth loop impedance (Z_L) values for MCBs & MCCBs

Below are the maximum permissible values of Z_L to obtain disconnection in 0.4 & 5 seconds

	Rated	Max let-through			Max Z_L (ohms)	
	trip	energy (kA2s) at PSCC			0.4	5
Type	**In**	**3kA**	**6kA**	**10kA**	**Secs**	**Secs**
MBN/	6	5.9	10.5	15	8	8.8
NBN	10	6.5	12.2	21.5	4.8	5.33
B curve	16	8.0	17.5	30	3	3.33
	20	8.8	19.5	34	2.4	2.66
	25	10	21	38	1.92	2.14
	32	11	24	42	1.5	1.66
	40	12.5	29	50	1.2	1.33
	50	15	34	61	0.96	1.06
	63	16	38	72	0.76	0.84
NCN/HM	0.5	0.01	0.01	0.01	48	120
C curve	1	4.0	7.0	10	24	53
	2	4.0	7.0	10	12	26
	3	5.0	10.0	15	8	18.78
	4	5.9	10.5	15	6	13.56
	6	5.9	10.5	15	4	8.8
	10	6.5	12.2	21.5	2.4	5.33
	16	8.0	17.5	30	1.5	3.33
	20	8.8	19.5	34	1.2	2.66
	25	10	21	38	0.96	2.14
	32	11	24	42	0.75	1.66
	40	12.5	29	50	0.6	1.33
	50	15	34	61	0.48	1.06
	63	16	38	72	0.38	0.84
	80				0.30	0.66
	100				0.24	0.53
NDN	6	5.9	10.5	15	2	8.8
D curve	10	6.5	12.2	21.5	1.2	5.33
	16	8.0	17.5	30	0.75	3.33
	20	8.8	19.5	34	0.6	2.66
	25	10	21	38	0.48	2.14
	32	11	24	42	0.37	1.66
	40	12.5	29	50	0.3	1.33
	50	15	34	61	0.24	1.06
	63	16	38	72	0.19	0.84

Table 40

	Rated	Max Z_L (ohms)	
	trip	0.4	
Type	**In**	**secs**	**5 secs**
H125 fixed mag. trip	16	0.2	1.9
	20	0.2	1.5
	25	0.2	1.2
	32	0.2	0.94
	40	0.2	0.75
	50	0.2	0.6
	63	0.2	0.48
	80	0.2	0.38
	100	0.2	0.3
	125	0.2	0.24
H 250 mag. trip set to max	160	0.125	0.125
	200	0.10	0.10
	250	0.08	0.08
H 250 mag. trip set to min	160	0.25	0.25
	200	0.20	0.20
	250	0.16	0.16
H 400 mag. trip set to max	320	0.06	0.06
	400	0.05	0.05
H 400 mag. trip set to min	320	0.13	0.13
	400	0.10	0.10
H 800 mag. set to max	500	0.05	0.05
	630	0.03	0.03
	800	0.03	0.03
H 800 mag. trip set to min	500	0.10	0.10
	630	0.06	0.06
	800	0.05	0.05

Table 41

These values have been calculated using the formula Z_L = Uoc/Ia taken from appendix 3 of EN7671: 1992, taking into account the 20% tolerance stated in section 8.3.3.1.2 of EN 60947-2. Uoc is the open circuit voltage of the REC transformer taken at 240V. Ia is the current causing operation of the protective device within the specified time. Calculate from Im x 1.2.

Full table as Apps guide (Table 27)