ABB SACE DIVISION
LB-PMI

Technical article

The “strange” numbers of circuit-breaker rated currents

Abstract

The rated currents of the circuit-breakers, the cross-sectional areas, the transformer power and the various other characteristic quantities of electrical equipment are represented by a series of numbers 10, 12.5, 16, 20, 25, 32, ... not immediately understandable. This article explains the origin of such series and illustrates who invented it and the reason why; the rated currents of ABB SACE circuit-breakers do not escape these "strange" numbers.

The "strange" numbers

The electrotechnical world is ruled by a series of numbers which seem, at first impact, outside any logic; when speaking of circuit-breakers we can observe that their rated currents are equal to 10, 12.5, 16, 20, 25, 32, ... A, when speaking of cables we have cross-sectional areas of 1.5, 2.5, 4, 6, 10, 16, 25, ... mm^2, and so on, also for the transformers, whose powers are 160, 200, 250, 315, 400, ... kVA.

If we left the habit of counting in the most immediate way for us (10, 20, 30, 40, 50, ...), we should thank an engineer as clever as a fox (in name and in deed).

Charles Renard

The series of "strange" numbers just mentioned "was born" thanks to Charles Renard[1] (1847-1905), a French army engineer Col., who after the Franco-Prussian war of 1870/71, started to work for the French Air Force. In 1884, together with his brother Paul and with Arthur C. Krebs, he built the military dirigible 'La France' which made its first flight on 9th August 1984 and which was presented to the Paris Universal Exposition in 1889 (event remembered because of the construction of the Eiffel Tower).

The men of genius are often remembered not because of their great works, but thanks to the solutions they have found to everyday problems. That's how Col. Renard has found his fame: not because he built a dirigible, but because he introduced a normalization system regarding the overall dimensions of the mechanical components with the purpose of reducing the number of manufactured pieces fulfilling at the same time any important requirement. His normalization system had his moment of glory in 1952 when its validity was recognized by the ISO Standard. This system is still in use.

Renard's series

Let's try to explain which are the advantages of this normalization system by supposing the need to produce steel pipes to satisfy the market's

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[1] In the French language "renard" means fox.

requirements with diameters from 10 to 100 mm. The most immediate choice to decide which diameters to manufacture is producing 10 pipes with diameters in arithmetic progression, e.g. 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 mm (arithmetic progression with common difference 10).

If the user needed a pipe with 92 mm diameter, he should use a pipe with 100 mm diameter, thus exceeding by 8.7% the wanted value; if he needed a pipe with 12 mm diameter, he would use a pipe with 20 mm diameter thus exceeding his real need by 66.6%. Thus the arithmetic progression is not very accurate for small dimensions, whereas in the case of large dimensions the elements result too little different from one another.

It is evident that the user wants a 'fine' production in order to find always the product suitable for his own requirements, whereas the manufacturer tends to rationalize the production in a 'discrete' way. Renard invented his series to meet both the requirements of the user as well as those of the manufacturer.

To that purpose, the engineer Col. suggested that a geometric progression[2] should be used and, according to it, to cover the production of pipes with diameter from 10 to 100 mm, the following diameters should be manufactured (geometric progression with common difference 10):

- 10, 12.5, 16, 20, 25, 32, 40, 50, 63, 80, 100.

As already said, a user needing a 92 mm diameter would use 100 mm thus exceeding of 8.7% only his needs, but if he needed 12 mm we should use 12.5 thus exceeding his needs of 4.2% only.

As a matter of fact the Renard's series is the series which minimizes the maximum relative error if any number is replaced with the nearest Renard number.

The Renard series are geometric progressions with common difference n:

$$F(i+1) = F(i) \cdot 10^{\frac{1}{n}}$$

with n = 5, 10, 20, 40, and are indicated with R5, R10, R20, R40.

The number values in sequence in the Renard series divide the logarithmic unit into n parts with percentage increases of 60% for R5, 25% for R10, 12% for R20, 6% for R40 respectively.

With reference to the previous example it is possible to demonstrate how producing pipes or circuit-breakers the rated currents of which belong to an

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[2] in an arithmetic progression the difference between two numbers in sequence is constant, whereas in a geometric progression the ratio between two successive numbers is constant. The ratio between a number and the previous one takes the name of "common ratio or scale factor".

arithmetic progression with common difference 10 a maximum relative error equal to 81.8 % is obtained, whereas by applying the Renard series R10 a maximum relative error equal to 25% is obtained.

Rated currents of ABB SACE circuit-breakers

R5 and R10 series are mostly used in the electrotechnical sector and in particular ABB SACE automatic circuit-breakers have their rated currents derived from the Renard series with common difference 10 (R10 series) (Tables 1 and 2).

SACE Tmax XT – Tmax T								
In [A]	**XT1**	**XT2**	**XT3**	**XT4**	**T4**	**T5**	**T6**	**T7**
1.6		•						
2		•						
2.5		•						
3.2		•						
4		•						
5		•						
6.3		•						
10		•						
12.5		•						
16	•	•						
20	•	•		•				
25	•	•		•				
32	•	•		•				
40	•	•		•				
50	•	•		•				
63	•	•	•	•				
80	•	•	•	•				
100	•	•	•	•				
125	•	•	•	•				
160	•	•	•	•				
225				•				
250			•	•				
320					•	•		
400						•		
630						•	•	
800							•	
1000							•	•
1250								•
1600								•

Table 1: Rated current of ABB SACE Tmax XT and Tmax T molded-case circuit-breakers

	Emax					
In [A]	**X1**	**E1**	**E2**	**E3**	**E4**	**E6**
400	●	●	●	●		
630	●	●	●	●		
800	●	●	●	●	●	●
1000	●	●	●	●	●	●
1250	●	●	●	●	●	●
1600	●	●	●	●	●	●
2000			●	●	●	●
2500				●	●	●
3200				●	●	●
4000					●	●
5000						●
6300						●

Table 2: Rated currents of ABB SACE Emax air circuit-breakers

Also the power of transformers derive from the Renard series of common difference 10. Table 3 shows an example of table for transformer protection where for each power the suitable ABB SACE circuit-breaker is given. The complete tables for different secondary voltages and for transformers in parallel are given in the catalogues and technical documents.

Transformer				Main circuit-breaker	
S_n [kVA]	**u_k** %	**I_n** [A]	**I_k** [kA]	**Type**	**In** [A]
63	4	91	2.2	XT1B160	100
100	4	144	3.6	XT1B160	160
125	4	180	4.5	XT3N250	200
160	4	231	5.7	XT3N250	250
200	4	289	7.2	T4N320	320
250	4	361	8.9	T5N400	400
315	4	455	11.2	T5N630	630
400	4	577	14.2	T5N630	630
500	4	722	17.7	T6N800	800
630	4	909	22.3	T7S1000/X1B1000	1000
800	5	1155	22.6	T7S1250/X1B1250	1250
1000	5	1443	28.1	T7S1600/X1B1600	1600
1250	5	1804	34.9	E2B2000	2000
1600	6.25	2309	35.7	E3N2500	2500
2000	6.25	2887	44.3	E3N3200	3200
2500	6.25	3608	54.8	E4S4000	4000
3125	6.25	4510	67.7	E6H5000	5000

Table 3: ABB SACE circuit-breakers for switching and protection of transformers (secondary at 400V)