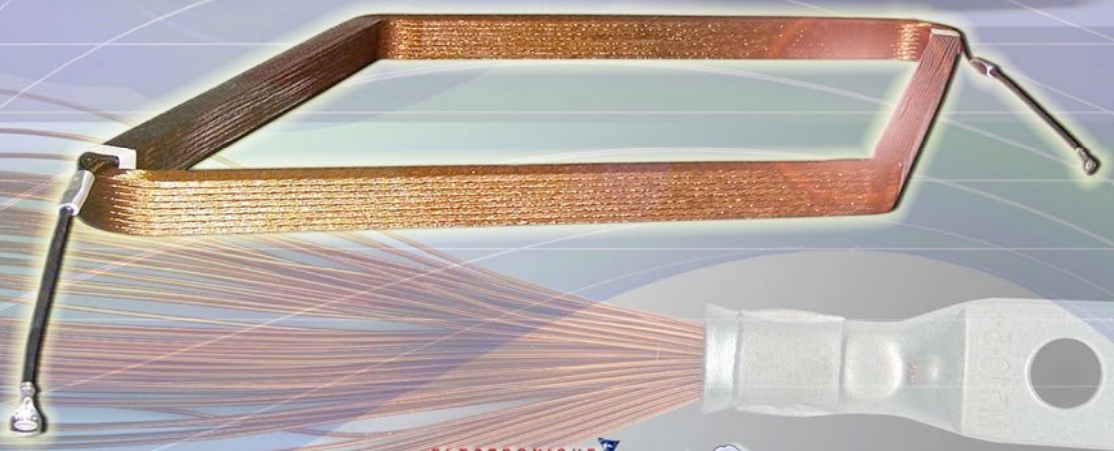
Winding Wires

Lil BREVET

Evolution of the implementation processes



ELECTRONIQUE AMR

WINDING WIRES

PRODUCTS DEVELOPMENT

AND

NEW IMPLEMENTATION

PROCESSES

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With the kind support of our Partner

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FOREWORD

The Profession of winding is an old craft that is not often seen revolution or even technological change.
Like all businesses established long dates, the Profession of winding has a huge experience and great potential.

The rapid progress in Converting Energy Inverters, choppers, Speed drives, power supplies ... make that wound circuits must evolve in response to new market switching elements.

This book aims to present the state of the current art and the major developments enjoyed the manufacture of rotary machines, Transformers and more generally windings.

These important developments have been made possible thanks to the Power Electronics and through the development of High Performance Polymers.

March 2015

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1 - GENERALITIES

INTRODUCTION

The enameled winding wires, Copper but Aluminum also, are isolated through various enameling varnish characteristics suited to their use according to different standards IEC or UL (NEMA), mainly on the temperature Class.

Indeed, the temperature conditions all the other features :

- Dielectrics
- Mechanical
- Chemical
- Resistance to radiation
- Aging

The insulation of a wire is determined according to the need :

- The dimensional characteristics (thickness of enamel or degree of the wire)
- Its mechanical stresses (Holding the enamel on the driver, etc ...)
- The breakdown voltage and the number of electrical faults
- Its Thermal characteristics (class T ° C Thermoplasticity, etc ...)
- Its chemical characteristics (resistance to solvents, oils, coolants, etc ...)
- Its possible resistance to ionizing radiation (Nuclear, etc ...)

User requirements are so diverse, it is necessary to establish standards based on need specifications.

The IEC 60317 with its specifications for Specifics Types of Winding Wires allows a classification based on the wide variety of products.

It should not be confused:

• Class temperature of a device (Engine) according ATEX (Explosive Atmosphere) with 79-10 IEC, EN 50014, 50015, 50017, 50018, 50019, 50020, 50021, 50281-1-1 and 2, etc ...

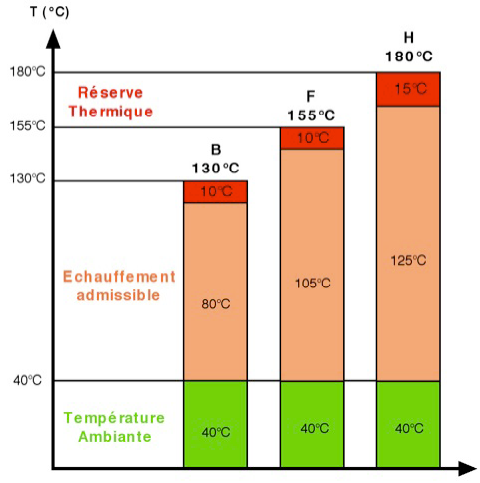
	CLASSE DE TEMPÉRATURE SUIVANT EN 50014					
CLASSE DE TEMPÉRATURE	T1	T2	T3	T4	T5	T6
TEMPÉRATURE DE SURFACE	450°C	300°C	200°C	135°C	100°C	85°C

and,

• The Temperature Class of the electrical insulators, which is the temperature calculated by extrapolation after a thermally accelerated aging, such that the properties are at least equal to 50% of their original values after aging 20 000 h (Arrhenius law) .

Classe de température des isolants

A	105 °C
B	130 °C
F	155 °C
H	180 °C
N	200 °C
R	220 °C
S	240 °C
C	> 240 °C



Température de FONCTIONNEMENT de quelques isolants

Polyéthylène	90 °C
Polyuréthane	90 °C
Polyamide	100 °C
Papier Imprégné	120 °C
Polycarbonate	130 °C
Mylar	150 °C
Nylon	150 °C
Silicone	250 °C
Teflon	260 °C
Verre	600 °C
Mica	750 °C
Porcelaine	1300 °C

La durée de vie d'un appareil électrique est limitée par la température à laquelle sont soumis les isolants.

Plus la température est élevée, plus la durée de vie est réduite.
La durée de vie d'un appareil diminue de moitié à chaque élévation de température de 10 °C.

Un moteur qui possède une durée de vie de 8 ans à 105 °C aura une durée de vie de 4 ans à 115 °C, de 2 ans à 125 °C et de 1 an à 135 °C

2 - SELF-BONDING

3 - WINDINGS

ROTATING MACHINES

INTRODUCTION TO ROTATING MACHINES

The rules of magnetism are identical, there are many similarities between the Transformers and Rotating Machines on the use of materials (Copper, Aluminum, steel sheet, insulation, etc ...).

The requirements differ, however, in temperature and winding techniques.
The motor winding often uses the technique of automatic Winding-Inserting or poles on winding technique.

The agglomeration of the wires is also different because the mechanical stresses, particularly on wound rotors can be very high.

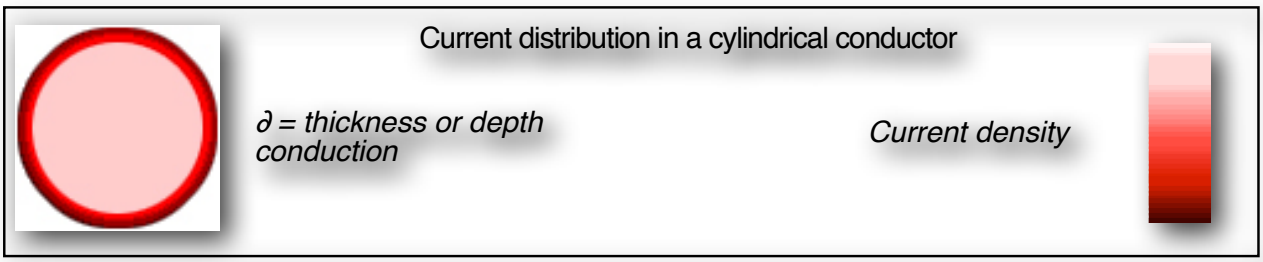
Class temperature of an engine is becoming higher and insulation should be entitled to the same class temperature.

4 - FROM COPPER TO ALUMINIUM

5 - LITZ WIRES AND ENERGY CONVERSION

THICKNESS CALCULATING FUNCTION OF THE FREQUENCY (1)

We will, at first, determine the thickness of the penetration of the current in the conductor cross section Copper and Aluminium, not taking into account the current gradient in the thickness as shown in the drawings below.



$$\delta = \sqrt{\frac{2.\rho}{\omega.\mu}} = \sqrt{\frac{2.\rho}{2\pi.F.\mu}} = \sqrt{\frac{\rho}{\pi.F.\mu}}$$

$$\delta_{Cu} = \sqrt{\frac{17{,}094.10^{-9}}{\pi.F.4\pi.10^{-7}}} = \frac{0{,}0658}{\sqrt{F}} \text{ m}$$

$$\delta_{Al} = \sqrt{\frac{28{,}000.10^{-9}}{\pi.F.4\pi.10^{-7}}} = \frac{0{,}0842}{\sqrt{F}} \text{ m}$$

$\delta =$ Thickness in m

$\mu =$ Permeability in H/m (μ_{Cu} & $\mu_{Al} = 4\pi.10^{-7} H/m$)

The absolute permeability diamagnetic materials (Silver, Copper) and paramagnetic (Aluminium) is substantially equal to that of the vacuum : 4π.10-7 H/m.

$\rho =$ Resistivity in Ω.m ($\rho_{Cu} = 17{,}094.10^{-9}$ & $\rho_{Al} = 28{,}000.10^{-9}$)

F = Fréquency in Hz

It may be deduced that the effective conductor section is = $S_{Cu} = \pi.(r^2 - (r-\delta)^2)$

HF RESISTANCE CALCULATION

We saw earlier that the useful section of an AC conductor at 20 ° C is :

$S_{Cu} = \pi.(r^2 - (r-\delta)^2)$ avec $\delta = {0,0658}/{\sqrt{F}}$ for Copper.

that resistance is $R_0 = \rho.\frac{l}{S_{Cu}}$ avec $\rho_{Cu} = 0,017094\Omega.mm^2/m$ and $\rho_{Cu} = 0,02800\Omega.mm^2/m$

and that the resistance of a conductor varies with the temperature according to the equation $R = R_0.(1+\lambda.\Delta T)$ with $\lambda_{Cu} = 0,00396$ and $\lambda_{Al} = 0,00400$

Replacing in each equation is obtained :

$R_{AC} = \rho.\frac{l.(1+\lambda.\Delta T)}{\pi.(r^2-(r-\delta)^2)}$ for a strand and therefore n strands : $R_{ACT} = \rho.\frac{l.(1+\lambda.\Delta T)}{\pi.(r^2-(r-\delta)^2)}.\frac{1}{n}$

R_{AC} is the Alternative Resistance (Not to be confused with the Impedance in AC)

$R_{DC} = \rho.\frac{l.(1+\lambda.\Delta T)}{\pi.r_a^{\,2}}$ $Num = \rho.l.(1+\lambda.\Delta T)$

R_{DC} is the Resistance measured in DC

It's easy to establish a computer program which provides $\frac{R_{ACT}}{R_{DC}}$ to the operating temperature.

By analyzing the signal, we can in addition to the heating due to the fundamental frequency, add the heating due to the significant harmonics in accordance with the topology of the converter.

The developed program can easily calculate the diameter and number of the composition of the cable strands.

Simply enter the topology of the converter, the nature of the magnetic circuit and its gap, the fundamental switching frequency, the operating temperature, the nature of the conductor (copper or aluminum), the intensity and shape of the current, voltage and shape.

FILLING FACTOR (2)

Exemple de calcul du taux de remplissage en fonction du Ø et du Grade du Fil

FILS CUIVRE STANDARDS												FILS CUIVRE THERMO-ADHERENTS					
Ø	Section	Masse	Grade 1	D		Grade 2	D		Grade 3	D		Grade 1B	D		Grade 2B	D	
(mm)	mm²	g/m		maxi			maxi			maxi			maxi			maxi	
0,010	0,0000785	0,0007	7 286 sp	0,014	0,46	6 313 sp	0,016	0,35	5 526 sp	0,019	0,25	6 563 sp	0,016	0,35	5 778 sp	0,018	0,28
0,012	0,0001150	0,0010	6 375 sp	0,016	0,52	5 611 sp	0,018	0,41	5 000 sp	0,021	0,30	5 833 sp	0,018	0,41	4 952 sp	0,021	0,30
0,014	0,0001539	0,0014	5 667 sp	0,018	0,55	5 050 sp	0,02	0,44	4 565 sp	0,023	0,34	5 250 sp	0,02	0,44	4 522 sp	0,023	0,34
0,016	0,0002011	0,0018	5 100 sp	0,02	0,58	4 591 sp	0,022	0,48	4 200 sp	0,025	0,37	4 773 sp	0,022	0,48	4 160 sp	0,025	0,37
0,018	0,0002545	0,0023	4 636 sp	0,022	0,61	4 208 sp	0,024	0,51	3 889 sp	0,027	0,40	4 375 sp	0,024	0,51	3 852 sp	0,027	0,40
0,019	0,0002835	0,0025	4 435 sp	0,023	0,62	3 885 sp	0,026	0,48	3 621 sp	0,029	0,39	4 200 sp	0,025	0,52	3 714 sp	0,028	0,42
0,020	0,0003142	0,0028	4 255 sp	0,024	0,63	3 846 sp	0,027	0,50	3 500 sp	0,030	0,40	4 000 sp	0,026	0,54	3 571 sp	0,029	0,43
0,021	0,0003464	0,0031	3 923 sp	0,026	0,59	3 607 sp	0,028	0,51	3 387 sp	0,031	0,42	3 621 sp	0,029	0,48	3 355 sp	0,031	0,42
0,022	0,0003801	0,0034	3 778 sp	0,027	0,60	3 367 sp	0,03	0,49	3 182 sp	0,033	0,40	3 500 sp	0,03	0,49	3 152 sp	0,033	0,40
0,023	0,0004155	0,0037	3 643 sp	0,028	0,61	3 258 sp	0,031	0,50	3 000 sp	0,035	0,39	3 387 sp	0,031	0,50	3 059 sp	0,034	0,42
0,024	0,0004524	0,0040	3 517 sp	0,029	0,62	3 156 sp	0,032	0,51	2 917 sp	0,036	0,40	3 281 sp	0,032	0,51	2 971 sp	0,035	0,43
0,025	0,0004909	0,0044	3 389 sp	0,031	0,59	3 076 sp	0,034	0,49	2 763 sp	0,038	0,39	3 278 sp	0,034	0,49	2 898 sp	0,037	0,41
0,027	0,0005726	0,0051	3 091 sp	0,033	0,61	2 806 sp	0,036	0,51	2 561 sp	0,041	0,39	2 838 sp	0,037	0,48	2 600 sp	0,04	0,41
0,028	0,0006158	0,0055	3 000 sp	0,034	0,62	2 658 sp	0,038	0,49	2 442 sp	0,043	0,38	2 763 sp	0,038	0,49	2 476 sp	0,042	0,40
0,030	0,0007069	0,0063	2 757 sp	0,037	0,60	2 463 sp	0,041	0,49	2 283 sp	0,046	0,39	2 500 sp	0,042	0,46	2 261 sp	0,046	0,39
0,032	0,0008042	0,0071	2 702 sp	0,039	0,61	2 439 sp	0,043	0,50	2 188 sp	0,048	0,40	2 564 sp	0,044	0,48	2 298 sp	0,048	0,40
0,034	0,0009079	0,0081	2 488 sp	0,041	0,62	2 196 sp	0,046	0,50	2 059 sp	0,051	0,40	2 234 sp	0,047	0,47	2 000 sp	0,052	0,39
0,036	0,0010179	0,0090	2 318 sp	0,044	0,61	2 061 sp	0,049	0,49	1 944 sp	0,054	0,40	2 100 sp	0,050	0,47	1 891 sp	0,055	0,39
0,038	0,0011341	0,0101	2 217 sp	0,046	0,62	1 980 sp	0,051	0,50	1 875 sp	0,056	0,42	2 019 sp	0,052	0,48	1 825 sp	0,057	0,40
0,040	0,0012566	0,0112	2 127 sp	0,049	0,60	1 941 sp	0,054	0,50	1 780 sp	0,059	0,42	2 020 sp	0,055	0,48	1 834 sp	0,060	0,40
0,043	0,0014522	0,0129	1 962 sp	0,052	0,62	1 741 sp	0,058	0,50	1 667 sp	0,063	0,42	1 780 sp	0,059	0,48	1 600 sp	0,065	0,40
0,045	0,0015904	0,0141	1 855 sp	0,055	0,61	1 656 sp	0,061	0,49	1 591 sp	0,066	0,42	1 694 sp	0,062	0,48	1 529 sp	0,068	0,40
0,048	0,0018096	0,0161	1 729 sp	0,059	0,60	1 554 sp	0,065	0,49	1 500 sp	0,070	0,43	1 567 sp	0,067	0,47	1 425 sp	0,073	0,39
0,050	0,0019635	0,0175	1 694 sp	0,060	0,63	1 538 sp	0,066	0,52	1 458 sp	0,072	0,44	1 587 sp	0,068	0,49	1 449 sp	0,074	0,41
0,053	0,0022062	0,0196	1 613 sp	0,064	0,62	1 468 sp	0,070	0,52	1 382 sp	0,076	0,44	1 514 sp	0,072	0,49	1 384 sp	0,078	0,42
0,056	0,0024630	0,0219	1 531 sp	0,067	0,63	1 397 sp	0,074	0,52	1 313 sp	0,080	0,44	1 442 sp	0,075	0,51	1 320 sp	0,082	0,42
0,060	0,0028274	0,0251	1 423 sp	0,072	0,63	1 304 sp	0,079	0,52	1 235 sp	0,085	0,45	1 345 sp	0,081	0,50	1 233 sp	0,088	0,42
0,063	0,0031172	0,0277	1 342 sp	0,076	0,62	1 234 sp	0,083	0,52	1 180 sp	0,089	0,45	1 273 sp	0,085	0,50	1 169 sp	0,092	0,43
0,067	0,0035257	0,0313	1 266 sp	0,080	0,64	1 169 sp	0,088	0,53	1 129 sp	0,093	0,47	1 201 sp	0,090	0,50	1 110 sp	0,098	0,42
0,070	0,0038485	0,0342	1 209 sp	0,083	0,65	1 120 sp	0,090	0,55	1 094 sp	0,096	0,48	1 147 sp	0,093	0,51	1 066 sp	0,100	0,44
0,071	0,0039592	0,0352	1 190 sp	0,084	0,65	1 104 sp	0,091	0,55	1 082 sp	0,097	0,49	1 129 sp	0,094	0,52	1 052 sp	0,101	0,45
0,075	0,0044179	0,0393	1 133 sp	0,089	0,64	1 053 sp	0,095	0,57	1 029 sp	0,102	0,49	1 078 sp	0,100	0,51	1 006 sp	0,106	0,45
0,080	0,0050265	0,0447	1 063 sp	0,094	0,66	990 sp	0,101	0,57	972 sp	0,108	0,50	1 015 sp	0,105	0,53	948 sp	0,112	0,46
0,085	0,0056745	0,0504	1 005 sp	0,100	0,66	939 sp	0,107	0,57	921 sp	0,114	0,50	962 sp	0,112	0,52	899 sp	0,119	0,46
0,090	0,0063617	0,0566	948 sp	0,105	0,67	889 sp	0,113	0,58	875 sp	0,120	0,51	909 sp	0,117	0,54	851 sp	0,125	0,47
0,095	0,0070882	0,0630	903 sp	0,111	0,66	847 sp	0,119	0,58	833 sp	0,126	0,52	864 sp	0,123	0,54	810 sp	0,131	0,48
0,100	0,0078540	0,0698	858 sp	0,117	0,66	806 sp	0,125	0,58	795 sp	0,132	0,52	820 sp	0,129	0,54	769 sp	0,137	0,48
0,106	0,0088247	0,0785	820 sp	0,123	0,67	769 sp	0,132	0,58	750 sp	0,140	0,52	777 sp	0,136	0,55	727 sp	0,145	0,48
0,110	0,0095033	0,0845	788 sp	0,128	0,67	743 sp	0,137	0,58	724 sp	0,145	0,52	751 sp	0,141	0,55	705 sp	0,150	0,49
0,112	0,0098520	0,0876	772 sp	0,130	0,67	730 sp	0,139	0,59	714 sp	0,147	0,53	738 sp	0,143	0,56	694 sp	0,152	0,49
0,118	0,0109359	0,0972	735 sp	0,136	0,68	694 sp	0,145	0,60	682 sp	0,154	0,53	704 sp	0,150	0,56	660 sp	0,159	0,50
0,120	0,0113097	0,1005	724 sp	0,138	0,69	684 sp	0,148	0,60	669 sp	0,157	0,53	692 sp	0,153	0,56	650 sp	0,163	0,49
0,125	0,0122718	0,1091	697 sp	0,144	0,68	658 sp	0,154	0,60	644 sp	0,163	0,53	664 sp	0,158	0,57	627 sp	0,168	0,50
0,130	0,0132732	0,1118	669 sp	0,150	0,68	634 sp	0,160	0,60	621 sp	0,169	0,54	640 sp	0,165	0,56	611 sp	0,175	0,50
0,132	0,0136848	0,1217	658 sp	0,152	0,68	625 sp	0,162	0,60	614 sp	0,171	0,54	631 sp	0,167	0,57	596 sp	0,177	0,50
0,140	0,0153938	0,1369	623 sp	0,160	0,69	590 sp	0,171	0,61	580 sp	0,181	0,54	597 sp	0,175	0,58	565 sp	0,186	0,51
0,150	0,0176715	0,1571	583 sp	0,171	0,70	554 sp	0,182	0,62	544 sp	0,193	0,55	558 sp	0,186	0,59	530 sp	0,197	0,53
0,160	0,0201062	0,1787	549 sp	0,182	0,70	519 sp	0,199	0,59	512 sp	0,205	0,55	526 sp	0,197	0,60	499 sp	0,209	0,53
0,170	0,0226980	0,2018	518 sp	0,194	0,70	491 sp	0,205	0,62	484 sp	0,217	0,56	497 sp	0,210	0,59	472 sp	0,221	0,54
0,315	0,0779311	0,6928	289 sp	0,349	0,74	276 sp	0,367	0,67	264 sp	0,384	0,61	279 sp	0,369	0,66	268 sp	0,387	0,60
0,335	0,0881413	0,7836	272 sp	0,372	0,74	261 sp	0,391	0,67	249 sp	0,408	0,61	264 sp	0,393	0,66	253 sp	0,412	0,60
0,355	0,0989798	0,8799	258 sp	0,392	0,74	247 sp	0,411	0,68	237 sp	0,428	0,62	249 sp	0,413	0,67	240 sp	0,432	0,61
0,375	0,110447	0,9819	245 sp	0,414	0,74	235 sp	0,434	0,68	224 sp	0,453	0,62	237 sp	0,436	0,67	228 sp	0,456	0,61
0,400	0,125664	1,1172	229 sp	0,439	0,75	221 sp	0,459	0,69	211 sp	0,478	0,64	223 sp	0,461	0,68	215 sp	0,481	0,63
0,425	0,141863	1,2612	216 sp	0,466	0,75	209 sp	0,488	0,69	198 sp	0,508	0,63	210 sp	0,489	0,69	203 sp	0,511	0,63
0,450	0,159043	1,4139	205 sp	0,491	0,76	198 sp	0,513	0,70	189 sp	0,533	0,65	199 sp	0,514	0,70	193 sp	0,536	0,64
0,475	0,177205	1,5754	194 sp	0,519	0,76	188 sp	0,541	0,70	179 sp	0,562	0,65	189 sp	0,543	0,69	184 sp	0,565	0,64
0,500	0,196350	1,7460	185 sp	0,544	0,77	179 sp	0,566	0,71	172 sp	0,587	0,66	180 sp	0,568	0,70	175 sp	0,590	0,65
0,530	0,220618	1,9610	175 sp	0,058	0,77	170 sp	0,600	0,71	162 sp	0,623	0,66	170 sp	0,600	0,71	166 sp	0,624	0,65
0,560	0,246301	2,1900	166 sp	0,606	0,77	161 sp	0,630	0,72	155 sp	0,653	0,67	162 sp	0,630	0,72	158 sp	0,654	0,66
0,600	0,282743	2,5140	155 sp	0,649	0,78	151 sp	0,674	0,72	145 sp	0,698	0,67	152 sp	0,674	0,72	148 sp	0,699	0,67
0,630	0,311725	2,7710	148 sp	0,679	0,78	144 sp	0,704	0,73	139 sp	0,728	0,68	145 sp	0,704	0,73	141 sp	0,729	0,68
0,670	0,352565	3,1340	140 sp	0,722	0,78	136 sp	0,749	0,73	131 sp	0,774	0,68	137 sp	0,748	0,73	133 sp	0,775	0,68
0,710	0,395919	3,5200	132 sp	0,762	0,79	128 sp	0,789	0,73	124 sp	0,814	0,69	129 sp	0,788	0,74	126 sp	0,815	0,69
0,750	0,441786	3,9270	125 sp	0,805	0,79	122 sp	0,834	0,73	117 sp	0,861	0,69	122 sp	0,832	0,74	119 sp	0,861	0,69
0,800	0,50265	4,4690	117 sp	0,855	0,79	115 sp	0,884	0,74	110 sp	0,911	0,70	115 sp	0,882	0,75	113 sp	0,911	0,70
0,850	0,56745	5,0450	111 sp	0,909	0,79	108 sp	0,939	0,74	104 sp	0,968	0,70	109 sp	0,937	0,75	106 sp	0,967	0,70
0,900	0,63617	5,6560	105 sp	0,959	0,80	102 sp	0,989	0,75	99 sp	1,018	0,71	103 sp	0,987	0,75	101 sp	1,017	0,71
0,950	0,70882	6,3010	99 sp	1,012	0,80	97 sp	1,044	0,75	94 sp	1,074	0,71	98 sp	1,041	0,76	96 sp	1,073	0,71
1,000	0,78540	6,9820	95 sp	1,062	0,80	92 sp	1,094	0,76	89 sp	1,124	0,72	93 sp	1,091	0,76	91 sp	1,123	0,72
1,060	0,88247	7,8450	89 sp	1,124	0,81	88 sp	1,157	0,76	85 sp	1,188	0,72	87 sp	1,154	0,77	85 sp	1,187	0,72
1,120	0,98520	8,7580	85 sp	1,184	0,81	83 sp	1,217	0,77	81 sp	1,248	0,73	83 sp	1,214	0,77	81 sp	1,247	0,73
1,180	1,09359	9,7220	81 sp	1,246	0,81	79 sp	1,279	0,77	77 sp	1,311	0,73	79 sp	1,276	0,78	77 sp	1,309	0,74
1,250	1,2272	10,910	76 sp	1,316	0,82	75 sp	1,349	0,78	73 sp	1,381	0,74	75 sp	1,346	0,78	73 sp	1,379	0,75
1,320	1,3685	12,170	72 sp	1,388	0,82	71 sp	1,422	0,78	69 sp	1,455	0,75	71 sp	1,419	0,78	69 sp	1,453	0,75
1,400	1,5394	13,690	68 sp	1,468	0,82	67 sp	1,502	0,79	66 sp	1,535	0,75	67 sp	1,499	0,79	66 sp	1,533	0,76
1,500	1,7671	15,710	64 sp	1,570	0,83	63 sp	1,602	0,80	61 sp	1,640	0,76	63 sp	1,602	0,80	62 sp	1,638	0,76
1,600	2,0106	17,870	60 sp	1,670	0,83	59 sp	1,706	0,80	58 sp	1,740	0,77	59 sp	1,702	0,80	58 sp	1,738	0,77
1,700	2,2698	20,180	56 sp	1,772	0,83	56 sp	1,809	0,80	55 sp	1,844	0,77	56 sp	1,805	0,80	55 sp	1,842	0,77
1,800	2,5447	22,620	53 sp	1,872	0,84	53 sp	1,909	0,81	52 sp	1,944	0,78	53 sp	1,905	0,81	52 sp	1,942	0,78
1,900	2,8353	25,210	51 sp	1,974	0,84	50 sp	2,012	0,81	49 sp	2,048	0,78	50 sp	2,008	0,81	49 sp	2,046	0,78
2,000	3,1416	27,930	48 sp	2,074	0,84	48 sp	2,112	0,81	48 sp	2,148	0,79	48 sp	2,108	0,82	47 sp	2,146	0,79
2,120	3,5299	31,380	46 sp	2,196	0,85	45 sp	2,235	0,82	44 sp	2,272	0,79						
2,240	3,9408	35,030	43 sp	2,316	0,85	43 sp	2,355	0,82	41 sp	2,392	0,80						
2,360	4,3744	38,890	41 sp	2,438	0,85	40 sp	2,478	0,82	39 sp	2,516	0,80						
2,500	4,9087	43,640	39 sp	2,578	0,85	38 sp	2,618	0,83	37 sp	2,656	0,80						
2,650	5,5155	49,030	37 sp	2,730	0,85	36 sp	2,772	0,83	35 sp	2,811	0,81						
2,800	6,1575	54,740	35 sp	2,880	0,86	34 sp	2,922	0,83	33 sp	2,961	0,81						
3,000	7,0686	62,840	32 sp	3,083	0,86	32 sp	3,126	0,84	31 sp	3,166	0,81						
3,150	7,7931	69,280	30 sp	3,233	0,86	30 sp	3,276	0,84	30 sp	3,316	0,82						
3,350	8,8141	78,360	29 sp	3,435	0,86	28 sp	3,479	0,84	28 sp	3,521	0,82						
3,550	9,8980	87,990	27 sp	3,635	0,86	27 sp	3,679	0,84	26 sp	3,721	0,83						
3,750	11,0447	98,190	26 sp	3,838	0,87	25 sp	3,883	0,85	25 sp	3,926	0,83						
4,000	12,5664	111,700	24 sp	4,088	0,87	24 sp	4,133	0,85	23 sp	4,176	0,83						
4,250	14,1863	126,100	23 sp	4,341	0,87	22 sp	4,387	0,85	22 sp	4,431	0,83						
4,500	15,9043	141,400	21 sp	4,591	0,87	21 sp	4,637	0,85	21 sp	4,681	0,84						
4,750	17,7205	157,500	20 sp	4,843	0,87	20 sp	4,891	0,86	20 sp	4,936	0,84						
5,000	19,6350	174,600	19 sp	5,093	0,87	19 sp	5,141	0,86	19 sp	5,186	0,84						

CONCLUSIONS ON THE LITZ WIRES (1)

The Power Electronics, in energy conversion, limited, there are still a few years, the power of the devices.

They are currently the windings and magnetic circuits that require the most work in research and development.

The percentage losses walk up in herds ..., and we must avoid leaving reproduce ... Operating temperatures and pressures are increasing, which requires new insulation wires polymer.

The ability to work in high frequencies Strong Currents and Elevated Voltages requires to completely review the calculation and production tools to adapt new industrial products that reach the market.

• Reduction in size of conventional magnetic circuits, implies a reduction of electrical circuits with a significant saving of raw materials (Cu or Al), but requires a higher value added processing.

• The Litz wires Aluminum Thermal allow members to make additional step towards the establishment of "technological bricks" in the field of the coil:

• The Litz wires provide access to high frequencies.

• The Thermo-setting Technology by Joule Effect allows the realization of complex coils and more efficient forms (better resistance to Short Circuits).

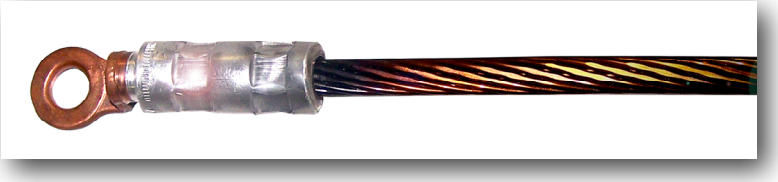
• Aluminium has significant advantages in price.

We saw earlier (page 114) that the HF penetration current is more important in Aluminum wire than in Copper one.

If we think with a single conductor to equivalent voltage fall, a circuit Aluminum is lighter 2.02 and 2.3 times more light at the same temperature elevation with respect to a copper circuit.

But if we include losses Skin Effect, an aluminum circuit is 3.5 times lighter than copper equivalent circuit.

The Litz wires are led to significant growth which demand will grow depending on the frequency increase in power systems and the possibility of connection of the wires with the COSDEM process.



6 - CONNECTORS AND TOOLS QUALITY

7 - THE EMC AND THE PERSONS PROTECTION

8 - STATISTICAL TOOLS FOR QUALITY

CAPABILITIES (2)

The capability is the ability of a process to be within the tolerance limits set beforehand.

A process for which no measured value is outside the control limits and for which we can pre mathematically calculate the results of future operations is said controlled.

Such a process is "Capable" if it meets the tolerance limits set beforehand.

Some terms must first ones defined:

Cp = long term capability index (relative to the width of tolerance)

Cm = short-term capability index (relative to the width of tolerance)

Cpk = long-term capability index (takes into account the situation in relation to tolerance limits)

Cmk = short-term capability index (takes into account the situation in relation to tolerance limits)

How is it calculated? Very simply, the Cp & Cpk and the Cm & Cmk are calculated as follows:

$$C_{p(m)} = \frac{T_S - T_i}{6 \times \sigma} \qquad C_{pk(mk)} = \frac{\min (T_S - \sigma , \sigma - T_i)}{3 \times \sigma}$$

T_S = tolérance supérieure

T_i = tolérance inférieure

- Yes, but what is σ ?

Easy, it is the standard deviation !!!

- And the standard deviation ... what is it?

Simple is the square root of the variance !!!

- Do not be afraid to abuse, but what is the variance?

It is the average of the squared deviations from the mean value of the measurements of a population or a representative sample.

That's it, Here we become the king of the statistics, but to do every day on thousands of values, it must be hell?

Yes, but AMR has concocted a small application that allows you to perform all these calculations automatically GESPROD complement the program.

D. Phase 4: impact assessment

This decline impacts that can result in a failure:
- System
- Its environment
- From People using the system

and induced effects and deducted.
Should be exploited tables FMECA and functional analysis. This evaluation is done in several stages:
- 1 Study the impact for the system itself.
- 2 Study of Neutralization repercussions in the system environment.
- 3 Study of alternative systems to the failed system.
- 4 Study of switching costs.

Examples of impact:
- Gravity
- Occurrence
- Frequency
- Effects
- Causes
- Criticality
- Fault isolation
- Prevent and Remedial the Effects
- Compensation for lack of participation in the general operation of the system

E. Step 5: Research other ways to reduce the risk index of priority to the value indicated in the Specifications.

At the end of the previous phase, all the risks associated with a failure mode is set.
Costs to neutralize the effects are listed.
One should look for other technical solutions or other functions to reduce to acceptable levels the risks.
It is common in this context of re-design parts of the system for reasons of lack of compliance with the law or breach of technical constraints.

F. Phase 6: compliance audit of the new index

Phase 6 is identical to Phase 3, since it uses the same process with new values it is appropriate to confirm or deny.

9 - VOC - REACH AND ROHS

GLOSSARY

EXPRESSION	SIGNIFICATION
6 σ	Dispersion for a normal distribution corresponding to 6 Standard Dispersion (SD)
AER	Annual Emission of Reference
AET	Annual Emission Target
Barrel	Cylindrical portion of a terminal for receiving the wire or cable
BipolaR	Transistor avec deux jonctions PN afin de réaliser des Transistors NPN & PNP
Breakdown voltage	Maximum voltage applied to an insulator before he became conductor
Capability	C'est la capacité d'un process à rester dans les valeurs limites définies
CAS	Numéro d'enregistrement unique auprès de la Banque de données Chemical Abstracts Service
CE Marking	Marking of electrical and electronic devices conform to EMC standards
Clamp Cage	Dispositif de connexion des fils par une lame élastique assurant une pression constante
CMR	Carcinogenic, Mutagenic, Reprotoxic
Conducted Disturbance	Refers to a disturbance transmitted by Conductor
Connectivity	All processing techniques "electrical" connections between separate conductors
Connector	Generally to a device for connecting two or more electrical circuits
Control Card	It defines the average value framed by the high and low limits
Coupling	Interaction between two or more electrical or electronic circuits.
Crystalline	Atomic structure organized into a geometric network (50 to 60% maximum)
Ctor instrumentation	Connector including metals avoid the occurrence of a voltage related to electrolytic coupling
DCE	Diagram of Control of Emissions
Declaration of Conformity	Specifying the technical report (s) program (s) for compliance testing to the Directive
Dielectric	Characteristic of the electric insulating material and supporting the joining parts
Dielectric strength	This is the value of the electric field in kV / mm can withstand insulation
Dimmer	Power controller to phase angle of the AC network
Dimmer	An apparatus for varying the speed of a motor
Distribution	Mathematical répartion a population that may be, normal, Poisson, Weibull, etc …
Disturbance	Changing the equilibrium state of an electric quantity by an external change
Dry extract	Amount of solid material after evaporation of the solvents
DSC	Differential Scanning Calometrics
EC (CE)	Commission Européenne
ECCI	European Confederation of Chemical Industries
EINECS	European Inventory of Existing Commercial Substances

EXPRESSION	SIGNIFICATION
Electric Shielding	Metal casing for isolating a device for radiation, in a field.
Electrical Earth	Soil that has potential arbitrarily set to 0V for all that is above
Electrolytic Action	Electrical cell phenomenon between two conductors of different nature with an electrolyte
ELNCS	European List of Notified Chemical Substances
Elongation	Measuring the flexibility of a material
EMC	Compatibilité ElectroMagnetic Compatibility
Emission	Production at a given point of a magnitude potentially disruptive conduct or radiated
Enamel	It provides the basic insulation of a single wire by depositing successive layers of varnish
Equipotential	Said of conductors or metal surfaces that are at the same potential.
European Directive	Text fixing the Community objectives to be achieved by the Member States (OJ 31.12.2004)
Experimental design	Collection significant steps of a process
Field	Space where a physical phenomenon manifests itself (eg power.) at any point.
FMECA	Risk prevention tool failure of a product and / or process
Gaussian	Curve Distribution of a population in a bell form
Glass Transition	Phase change of a material that changes from a glassy state to a hard and soft state
Grade	Characteristic of the thickness of the enamel layer (G1, G2, G3, G4, G1B, G2B)
Henry Line	Line to adjust a Gaussian distribution equation
HPV	High Production Volume
ICCA	International Council of Chemical Associations
IGBT	Insulated Gate Bipolar Transistor tTransistor Bipolaire à grille isolée)
Immunity	Insensitivity of an apparatus with respect to external disturbances
Insulation Breakdown	Perforation of insulating after exceeding the voltage
Inverter	Voltage converter to AC voltage
IUCLID 5	IUCLID 5 is the database for the registration of chemicals
Last Square	Fitting curve (or trend) of a disparate population
Macromolecule	Assembly of elementary particles, themselves derived from an atomic assembly
Mass	Common conductor which are connected the points of a circuit of a same potential
Monomer	Substance (usually organic) for the synthesis of a polymer
MOS	Metal Oxide Semiconductor
No Lens	Amorphous structure of the material (eg glass has a non-crystalline structure)
OECD	Organisation for Economic Co-operation and Development
Pareto Chart	Diagram showing the distribution of population according to the law 20/80
PBT	Persistent, Bioaccumulative and Toxic

EXPRESSION	SIGNIFICATION
Peel test	Test to characterize the enamel held on copper (or aluminum)
Pencil hardness	Method for measuring the hardness of enamel with the panel hardness of pencils.
Pin	Élément métallique d'un connecteur assurant le passage du courant entre deux conducteurs
Polymer	Material made of macromolecules (monomer) assembled repeatedly
Polymerization	Chemical reaction initiated Pressure AND Temperature (with or without catalyst)
POP	Poluants Organiques Persistants
Population	Limited set of products, components, etc ... analyzed for statistical calculations
Power Connector	Connector to carry high currents (1A to several thousand amperes)
PWM	Pulse Width Modulation
Radiated	Refers to a disturbance emitted by a driver or a remote antenna Victim
REACH	Registration Evaluation Authorization and restriction of Chemical
Regression	Statistical calculations for establishing the curve of evolution of a quantity
Resoftening Temperature	Softening starting temperature of a thermo-adhesive.
Reticulation	Three-dimensional assembly of macromolecules
Rheology	Is the study of the deformation and flow of the material under stress
RIP	REACH Implementation Projets
RoHS	Restriction of the Use of Certain Hazardous Substances
Screw Cage	Dispositif de connexion des fils par une lame poussée par une vis (la pression n'est pas cste)
SDS	Safety Data Sheet
Semi-Conducteur	Material with an electrical conductivity falling between a conductor and an insulator
Semi-Cristallin	Intermediate state of matter between crystal structure lapped by NC substance
Signal Connector (Plug)	Connector to convey weak currents (few µA to 1A)
Skin Effect	Surface current conduction phenomenon in function of the frequency
SMP	Solvent Management Plan
SPC	Statistical Process Control
Standard Deviation	Square root of the variance
SusceptibilitY	Constant of proportionality between size and the corresponding field
Switch	Generally a semiconductor capable of switching high currents
Tangent ∂	Characterized the dielectric losses as a function of temperature
Temperature Class	Temperature (° C) during operation of an insulator 20 000h lossy <50%
Temperature Index	Aging temperature after 20 000 hours with a 50% elongation
Terminal	Electrical component for connecting a wire to another conductor.

EXPRESSION	SIGNIFICATION
Thermal Class	Temperature (° C) following approval in principle to IEC or UL 34-18-21
Thermal Shock	Measurement of holding copper on enamel in an oven
Thermo-bonding	Characteristic of an enamel which may be polymerized by increasing the temperature
Thermoplasticity	Creep Temperature enamel pressure (Cut Throught)
Thermosetting	Product whose transformation is irreversible without breaking the molecular chain
Thyristor	Static switch of very high power controlled only ignition
Thyristor GTO & IGCT	Gate Turn Off & Integrated Gate Commutated Thyristor Thyristorslockable by the trigger
Tightening Torque	Torque applied to the screw to a terminal by a torque wrench
Tongue	Planar area of a terminal for establishing the connection of the terminal
Transistor	Electronic component for switching current (bipolar, MOS, IGBT)
Tribology	It is the study of the mechanical contact phenomena (mainly friction)
UCI	Union of Chemical Industries
UECI	Union of European Community Industries
Variance	Average of squared deviations by comparison with the average values
Varnish	Varnish of the term covers various insulation products, impregnating or protection
VEL	Values Emission Limits
VOC	Volatile Organic Compounds
vPvB	Very persitantes and very Bioaccumulative

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