TUTORIAL ON AC Resistance Calculation for Bare Stranded Conductors (TB345)

Prepared by Study Committee B2

Advisory Group 4 – Electrical Effects

January, 2009

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- Calculation of AC Resistance of Stranded Conductor
  - DC Resistance
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  - Core Losses (ACSR)
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Bare Conductor Resistance Overview

- Aluminum Strands carry 98% of current so Rdc <u>primarily</u> depends on aluminum conductivity and crossection area.
- Helical stranding 2% increase in Rdc
- RDC increases 4% per 10C
- Skin Effect increase is 1% to 10%
- For ACSR, Transformer effect is <20% for 1-layer and <5% (multi-layer) for >2 amps/kcmil

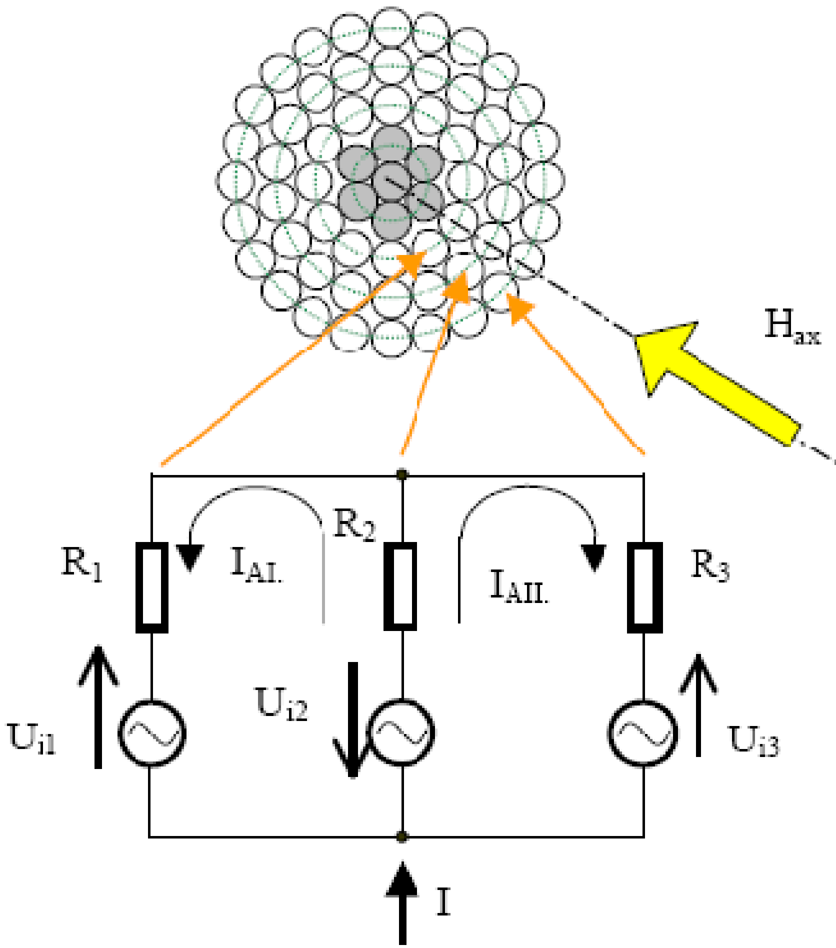
DC Resistance

$$R_{dc} = 4\,\rho_{20}\,[1 + \alpha_{20}\,(T - 20)] \,/\, \pi\, D_s^{\,2}$$

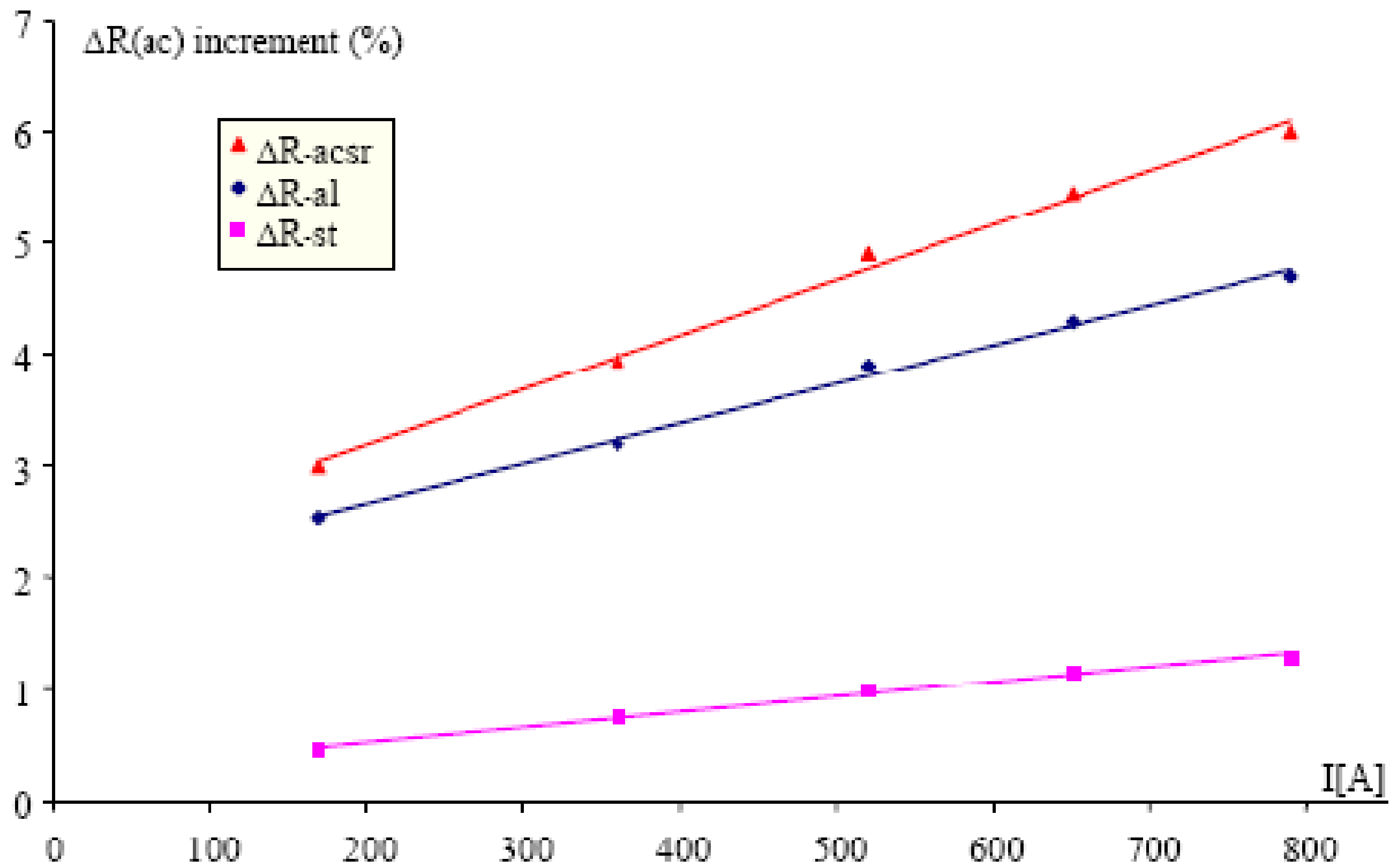
$$\frac{1}{R_{dc}} = \frac{\pi\, d_s^{\,2}}{4\,\rho_s}\left(1 + \sum_{1}^{n_s} \frac{6\, n_s}{k_{ns}}\right) + \frac{\pi\, d_a^{\,2}}{4\,\rho_a}\left(1 + \sum_{n_a+1}^{n_a} \frac{6\, n_a}{k_{na}}\right)$$

$$k_n = \left[1 + \left(\frac{\pi\, D_n}{\lambda_n}\right)^2\right]^{1/2}$$

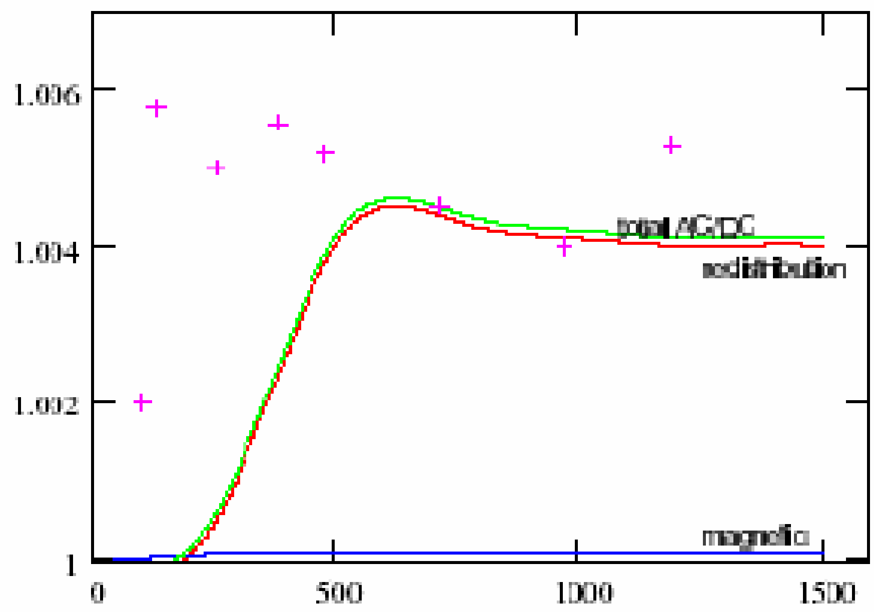
Transformer Effect



INCREASE IN RAC for Current



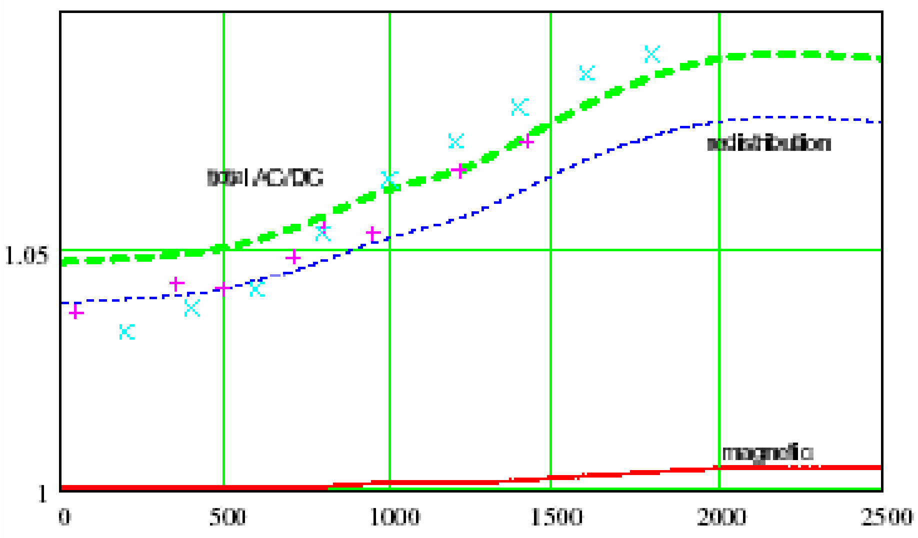
2-Layer ACSR



Notice that the core losses and transformer effect (magnetic coupling) is small for 2-layers of aluminum strands

Current (A)	Skin effect contribution	Current redistribution increment	Magnetic losses increment	Total AC/DC resistance ratio
0	0.000	0.000	0.000	1.000
250	0.004	0.0005	0.0001	1.0006
500	0.004	0.004	0.0001	1.0041
750	0.004	0.0043	0.0001	1.0044
1000	0.004	0.0041	0.0001	1.0042
1250	0.004	0.004	0.0001	1.0041
1500	0.004	0.004	0.0001	1.0041

3-Layer ACSR



Notice that the core losses and transformer effect (magnetic coupling) is stronger for 3-layers of aluminum strands

Current (A)	Skin effect contribution	Current redistribution increment	Magnetic losses increment	Total AC/DC resistance ratio
0	0.000	0.000	0.000	1.000
250	0.008	0.040	0.001	1.049
500	0.008	0.042	0.001	1.051
750	0.008	0.047	0.001	1.056
1000	0.008	0.053	0.002	1.063
1250	0.008	0.058	0.002	1.068
1500	0.008	0.066	0.003	1.077
1750	0.008	0.073	0.004	1.085
2000	0.008	0.077	0.005	0.090
2250	0.008	0.078	0.005	0.091
2500	0.008	0.077	0.005	0.090

Rac MathCadd Program

PROGRAM FOR CALCULATION OF AC RESISTANCE OF HELICALLY STRANDED CONDUCTORS

GENERAL INPUT DATA:

$f := 50$ Hz - frequency

$\mu_0 := 4 \cdot \pi \cdot 10^{-7}$ - magnetic permeability of the air

$\rho st := 0.1775$ $\frac{\Omega \cdot mm^2}{m}$ - specific resistance of steel, Code 1

$\alpha st := 0.00393$ $\frac{1}{degC}$ - temperature coefficient of steel

$\gamma st := 7.78$ $\frac{kg}{dm^3}$ - density of steel

$\rho aal := 0.0327$ $\frac{\Omega \cdot mm^2}{m}$ - specific resistance of alloy, Code 2

$\alpha aal := 0.00360$ $\frac{1}{degC}$ - temperature coefficient of alloy

$\gamma aal := 2.7$ $\frac{kg}{dm^3}$ - density of alloy

$\rho al := 0.028126$ $\frac{\Omega \cdot mm^2}{m}$ - specific resistance of aluminium, Code 3

$\alpha al := 0.00404$ $\frac{1}{degC}$ - temperature coefficient of aluminium

$\gamma al := 2.7$ $\frac{kg}{dm^3}$ - density of aluminium

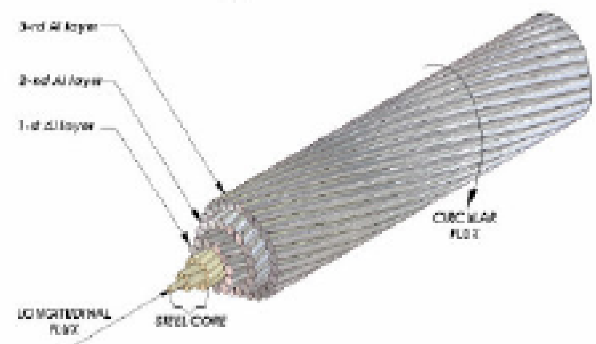
CONDUCTOR GEOMETRY DATA:

example: Grackle ACSR

$Nls := 3$ - number of steel layers

$Nlaa := 0$ - number of alloy layers

$Nla := 3$ - number of aluminium layers



$Nl := Nls + Nlaa + Nla$ $\quad Nl = 6$ - **total number of layers** (limited to 7)

$Mc_0 := 1$ - material code of 1st layer (first wire in centre assumed as 1st layer)

$nw_0 := 1$ $\quad dw_0 := 2.24$ - number and diameter (mm) of wires in 1st layer

$Layratio_0 := 0$ - lay ratio of 1st layer

Conclusions

- Aluminum Strands carry 98% of current so Rdc primarily depends on aluminum conductivity and crossection area.
- Helical stranding 2% increase in Rdc
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- For ACSR, Transformer effect is <20% for 1-layer and <5% (multi-layer) for >2 amps/kcmil