IEC 60287-3-2

Edition 2.0 2012-07

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Electric cables – Calculation of the current rating – Part 3-2: Sections on operating conditions – Economic optimization of power cable size

Câbles électriques – Calcul du courant admissible – Partie 3-2: Sections concernant les conditions de fonctionnement – Optimisation économique des sections d'âme de câbles électriques de puissance

IEC 60287-3-2:2012

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

Useful links:

IEC publications search - www.iec.ch/searchpub

The advanced search enables you to find IEC publications by a variety of criteria (reference number, text, technical committee,…).
It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available on-line and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary (IEV) on-line.

Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Liens utiles:

Recherche de publications CEI - www.iec.ch/searchpub

La recherche avancée vous permet de trouver des publications CEI en utilisant différents critères (numéro de référence, texte, comité d'études,…).
Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

Just Published CEI - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications de la CEI. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - www.electropedia.org

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 30 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (VEI) en ligne.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.

IEC 60287-3-2

Edition 2.0 2012-07

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Electric cables – Calculation of the current rating – Part 3-2: Sections on operating conditions – Economic optimization of power cable size

Câbles électriques – Calcul du courant admissible – Partie 3-2: Sections concernant les conditions de fonctionnement – Optimisation économique des sections d'âme de câbles électriques de puissance

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX **W**

ICS 29.060.20

ISBN 978-2-83220-151-0

Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTRIC CABLES – CALCULATION OF THE CURRENT RATING –

Part 3-2: Sections on operating conditions – Economic optimization of power cable size

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.

3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.

4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.

6) All users should ensure that they have the latest edition of this publication.

7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.

8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60287-3-2 has been prepared by IEC technical committee 20: Electric cables.

This second edition cancels and replaces the first edition, published in 1995 and its Amendment 1:1996. This edition consitutes a technical revision. This edition incorporates Amendment 2 which was not published separately due to the number of changes and pages.

The main changes with respect to the previous edition are as follows:

- update of the normative references;
- clarification of some symbols;
- correction of some formulae;
- introduction of a second example in Annex A for the calculation of the economic conductor size.

The text of this standard is based on the first edition, its amendment 1 and the following documents:

FDIS	Report on voting
20/1367/FDIS	20/1373/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60287 series can be found on the IEC website under the general title: *Calculation of the current rating.*

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

0.1 General part

The procedure generally used for the selection of a cable size leads to the minimum admissible cross-sectional area, which also minimizes the initial investment cost of the cable. It does not take into account the cost of the losses that will occur during the life of the cable.

The increasing financial and environmental cost of energy, together with the energy losses which follow from conductors operating at high temperatures, requires that cable size selection be considered on wider grounds. Rather than minimizing the initial cost only, the sum of the initial cost and the cost of the losses over the anticipated operational life of the system should be minimized. For this latter condition, a larger size of conductor than would be chosen based on minimum initial cost will lead to a lower power loss for the same current. This, when considered over its anticipated operational life, will reduce the energy losses and the total cost of the system. Where thermal consideration dictates the use of the largest practical conductor size, the installation of a second parallel cable circuit can result in a reduction in the total cost over the life of the installation.

The formulae and examples given in this standard are arranged to facilitate the calculation of the economic conductor size after factors such as system voltage, cable route, cable configuration and sheath bonding arrangements have been decided. Although these factors are not considered in detail, they have an impact on both the installation and operating costs of a cable system. The effect of changing any of the above factors on the total cost over the anticipated operational life of the system can be determined using the principles set out in this standard.

Future costs of energy losses during the anticipated operational life of the cable can be calculated by making suitable estimates of load growth and cost of energy. The most economical size of conductor is achieved when the sum of the future costs of energy losses and the initial cost of purchase and installation are minimized.

The saving in overall cost, when a conductor size larger than that determined by thermal constraints is chosen, is due to the considerable reduction in the cost of the joule losses compared with the increase in cost of purchase. For the values of the financial and electrical parameters used in this standard, which are not exceptional, the saving in the combined cost of purchase and operation is of the order of 50 % (see A.2.5). Calculations for much shorter financial periods can show a similar pattern.

A further important feature, which is demonstrated by examples, is that the savings possible are not critically dependent on the conductor size when it is in the region of the economic value, see Figure A.3. This has two implications:

a) the impact of errors on financial data, particularly those which determine future costs, is small. While it is advantageous to seek data having the best practicable accuracy, considerable savings can be achieved using data based on reasonable estimates;

b) other considerations with regard to the choice of conductor size which feature in the overall economics of an installation, such as fault currents, voltage drop and size rationalization, can all be given appropriate emphasis, without losing too many of the benefits arising from the choice of an economic size.

The formulae given in this standard are written for a.c. systems but they are equally applicable to d.c. systems. Clearly, for d.c. systems, the d.c. resistance is used in place of the a.c. resistance and the sheath and armour loss factors are set to zero.

0.2 Economic aspects

In order to combine the purchase and installation costs with costs of energy losses arising during the anticipated operational life of a cable, it is necessary to express them in comparable economic values, that is values which relate to the same point in time. It is convenient to use the date of purchase of the installation as this point and to refer to it as the "present". The "future" costs of the energy losses are then converted to their equivalent "present values". This is done by the process of discounting, the discounting rate being linked to the cost of borrowing money.

In the procedure given here, inflation has been omitted on the grounds that it will affect both the cost of borrowing money and the cost of energy. If these items are considered over the same period of time and the effect of inflation is approximately the same for both, the choice of an economic conductor size can be made satisfactorily without introducing the added complication of inflation.

To calculate the present value of the costs of the losses it is necessary to choose appropriate values for the future development of the load, annual increases in kWh price and annual discounting rates over the anticipated operational life of the cable, which could be 25 years or more. It is not possible to give guidance on these aspects in this standard because they are dependent on the conditions and financial constraints of individual installations. Only the appropriate formulae are given: it is the responsibility of the designer and the user to agree on the economic factors to be used.

The formulae proposed in this standard are straightforward, but in their application due regard should be taken of the assumption that the financial parameters are assumed to remain unchanged during the anticipated operational life of the cable. Nevertheless, the above comments on the effect of the accuracy of these parameters is also relevant here.

There are two approaches to the calculation of the economic size, based on the same financial concepts. The first, where a series of conductor sizes is being considered, is to calculate a range of economic currents for each of the conductor sizes envisaged for particular installation conditions and then to select that size whose economic range contains the required value of the load. This approach is appropriate where several similar installations are under consideration. The second method, which may be more suitable where only one installation is involved, is to calculate the optimum cross-sectional area for the required load and then to select the closest standard conductor size.

0.3 Other criteria

Other criteria, for example short-circuit current and its duration, voltage drop and cable size rationalization, should also be considered. However, a cable chosen to have an economical size of conductor may well be satisfactory also from these other points of view, so that when sizing a cable, the following sequence may be advantageous:

a) calculate the economic cross-sectional area;
b) check by the methods given in IEC 60287-1-1, in IEC 60287-2-1 and in the IEC 60853 series that the size indicated by a) is adequate to carry the maximum load expected to occur at the end of the economic period without its conductor temperature exceeding the maximum permitted value;
c) check that the size of cable selected can safely withstand the prospective short-circuit and earth fault currents for the corresponding durations;
d) check that the voltage drop at the end of the cable remains within acceptable limits;
e) check against other criteria appropriate to the installation.

To complete the field of economic selection, proper weight should be given to the consequences of interruption of supply. It may be necessary to use a larger cross-section of conductor than the normal load conditions require and/or the economic choice would suggest, or to adapt the network accordingly.

A further cost component may be recognized in the financial consequence of making a faulty decision weighted by its probability. However, in doing so one enters the field of decision theory which is outside the scope of this standard.

Thus, economic cable sizing is only a part of the total economic consideration of a system and may give way to other important economic factors.

0.4 Environmental impact

When determining optimum size for a given circuit, consideration should also be given to environmental impact. Based on the projected life of a circuit, the environmental impact of operational losses may well outweigh all other impacts in the life cycle and may justify a larger conductor size than that determined by economic factors alone. Further guidance can be found in IEC/TR 62125.

ELECTRIC CABLES –
CALCULATION OF THE CURRENT RATING –

Part 3-2: Sections on operating conditions – Economic optimization of power cable size

1 Scope

This part of IEC 60287 sets out a method for the selection of a cable size taking into account the initial investments and the future costs of energy losses during the anticipated operational life of the cable.

Matters such as maintenance, energy losses in forced cooling systems and time of day energy costs have not been included in this standard.

Two examples of the application of the method to hypothetical supply systems are given in Annex A.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60228, *Conductors of insulated cables*

IEC 60287-1-1, *Electric cables – Calculation of the current rating – Part 1-1: Current rating equations (100 % load factor) and calculation of losses – General*

IEC 60287-2-1, *Electric cables – Calculation of the current rating – Part 2-1: Thermal resistance – Calculation of thermal resistance*

IEC 60853 (all parts), *Calculation of the cyclic and emergency current rating of cables*

3 Symbols

The symbols used in this standard and the quantities which they represent are given in the following list:

a	annual increase in I_{max}	%
A_L	constant component of cost per unit length related to laying conditions, etc.	cu/m
A_S	variable component of cost per unit length related to conductor size	cu/(m·mm^2)
b	annual increase in P, not covered by inflation	%
B	auxiliary quantity defined by Formula (16)	–
c	annual increase in loss load factor	%
C	capacitance per core	F/m
CI	installed cost of the length of cable being considered	cu

$CI(S)$	installed cost of a cable as a function of its cross-sectional area	cu
CI_1	installed cost of the next smaller standard size of conductor	cu
CI_2	installed cost of the next larger standard size of conductor	cu
CJ	present value of the cost of joule losses during N years	cu
CT	total cost of a system	cu
D	demand charge each year	cu/(W·year)
d_c	diameter of conductor, including screen, if any	mm
D_i	diameter over insulation	mm
f	system frequency	Hz
F	auxiliary quantity defined by Formula (10)	cu/W
F_2	auxiliary quantity defined by Formula (27)	–
g	factor used in calculation of charging current losses	–
i	discounting rate used to compute present values	%
$I(t)$	load as a function of time	A
I_c	charging current per unit length	A/m
I_{max}	maximum load in first year i.e. the highest hourly mean value	A
L	cable length	m
N	period covered by financial calculations, also referred to as "anticipated operational life"	year
N_c	number of circuits carrying the same type and value of load	–
N_p	number of phase conductors per circuit	–
N_s	number of earthed sections in a single-core cable system	–
P	cost of one watt-hour at relevant voltage level	cu/(W·h)
Q	auxiliary quantity defined by Formula (8)	–
Q_v	auxiliary quantity defined by Formula (28)	–
r	auxiliary quantity defined by Formula (9)	–
r_v	auxiliary quantity defined by Formula (29)	–
R	a.c. resistance of conductor per unit length (considered to be a constant value at an average operating temperature, see Clause 4)	Ω/m
R_L	cable a.c. resistance per unit length, including the effect of λ_1 and λ_2, $R_L = R(1+ \lambda_1$ and $\lambda_2)$	Ω/m
$R_L(S)$	a.c. resistance per unit length of a conductor as a function of its area, including the effect of λ_1 and λ_2	Ω/m
R_{L1}	a.c. resistance per unit length of next smaller standard conductor size, including the effect of λ_1 and λ_2	Ω/m
R_{L2}	a.c. resistance per unit length of next larger standard conductor size, including the effect of λ_1 and λ_2	Ω/m
R_s	a.c. resistance of sheath, or screen, per unit length (considered to be a constant value at an average operating temperature)	Ω/m

S	cross-sectional area of a cable conductor	mm^2
S_{ec}	economic conductor size	mm^2
t	time	h
T	operating time at maximum joule loss	h/year
T_t	equivalent operating time at maximum loss, including dielectric loss	h/year
U_0	voltage between conductor and screen or sheath	V
W_{chc}	losses due to charging current in conductors	W
W_{chs}	losses due to charging current flowing in screen/armour	W
W_d	dielectric losses per unit length per phase	W/m
y_p	proximity effect factor, see IEC 60287-1-1	–
y_s	skin effect factor, see IEC 60287-1-1	–
α_{20}	temperature coefficient of conductor resistance at 20 °C	1/K
β	reciprocal of the temperature coefficient of resistivity of the conductor material at 0 °C. For aluminium β = 228, for copper β = 234,5	K
tan δ	loss factor of insulation	–
ε	is the relative permittivity of insulation	–
λ_1, λ_2	sheath and armour loss factors, see IEC 60287-1-1	–
μ	loss load factor, see the IEC 60853 series	–
ρ_{20}	conductor resistivity at 20 °C, see 5.2	Ω·m
θ	maximum rated conductor operating temperature	°C
θ_α	ambient average temperature	°C
θ_μ	mean operating conductor temperature	°C

The unit cu is an arbitrary currency unit.

4 Calculation of total costs

The total cost of installing and operating a cable during its anticipated operational life, expressed in present values, is calculated as follows. Note that all financial quantities are expressed in arbitrary currency units, (cu).

$$\text{The total cost} = CT = CI + CJ \text{ (cu)} \tag{1}$$

where

CI is the cost of the installed length of cable, in cu;

CJ is the equivalent cost at the date the installation was purchased, i.e. the present value, of the joule losses during an anticipated operational life of N years, in cu.

Evaluation of CJ

The total cost due to the losses is composed of two parts: a) the energy charge, and b) the charge for the additional supply capacity to provide the losses.

a) *Cost due to energy charge*

$$\text{Energy loss during the first year} = (I^2_{max} \times R_L \times L \times N_p \times N_c)T \text{ (W} \times \text{h)} \tag{2}$$

where

I_{max} is the maximum load on the cable during the first year, in A;

L is the length of cable, in m;

R_L cable a.c. resistance per unit length, including the effect of λ_1 and λ_2, $R_L = R(1 + \lambda_1 + \lambda_2)$.

The selection of the method of bonding the sheaths, screens or armour of single-core cables will have a significant effect on the losses due to circulating currents in these components. Where the system design permits, the bonding method should be selected to balance the cost of these losses over the life of the installation against the initial cost of installing the equipment and additional earth conductors required for certain bonding arrangements.

As the economic conductor size is usually larger than the size based on thermal considerations (i.e. the size determined by the use of IEC 60287-1-1, IEC 60287-2-1 and/or the IEC 60853 series), its temperature will be lower than the maximum permissible value. It is convenient to assume, in the absence of more precise information, that R_L is constant and has a value corresponding to a temperature of $(\theta - \theta_a)/3 + \theta_a$.

Here θ is the maximum rated conductor temperature for the type of cable concerned and θ_a is the ambient average temperature. Factor 3 is empirical, see Annex B.

NOTE 1 If greater precision is required (for example where the calculations do not indicate clearly which nominal conductor size should be chosen or the growth in load is such that its value during the final years is significantly higher than that of the first year) a better estimate of conductor temperature can be made using as a starting point the conductor size obtained from the approximate temperature given above.

Methods for making a more refined estimate of conductor temperature and resistance are given in Annex B. The economical size is then redetermined using the revised value of conductor resistance.

The effect of conductor resistance on the value of the economical size is small and it is seldom worthwhile to perform the iteration more than once.

N_p is the number of phase conductors per circuit;

N_c is the number of circuits carrying the same value and type of load;

T is the equivalent operating time at maximum loss, in h/year;

is the number of hours per year that the maximum current I_{max} would need to flow in order to produce the same total yearly energy losses as the actual, variable, load current;

$$T = \int_0^{8\,760} \frac{I(t)^2 \times dt}{I_{max}^2}$$

If the loss load factor μ is known and can be assumed to be constant during the anticipated operational life, then:

T is equal to $\mu \times 8\,760$

See the IEC 60853 series for the derivation of the loss load factor, in μ.

NOTE 2 The loss-load factor used in the IEC 60853 series is a daily average factor. The use of this factor as an annual average is a simplification which assumes that the circuit is in continuous operation and the load pattern for the circuit being considered remains constant throughout the year.

t is the time, in h;

$I(t)$ is the load current as a function of time, in A.

The cost of the first year's losses is:

$$= (I^2_{\max} \times R_L \times L \times N_p \times N_c) \times T \times P \text{ (cu)} \tag{3}$$

where

P is the cost of one watt-hour of energy at the relevant voltage level, in cu/(W·h).

b) *Cost due to additional supply capacity*

The cost of additional supply capacity to provide these losses is:

$$= (I^2_{\max} \times R_L \times L \times N_p \times N_c) \times D \text{ (cu/year)} \tag{4}$$

where

D is the demand charge per year, in cu/(W•year).

The overall cost of the first year's losses is therefore:

$$= (I^2_{\max} \times R_L \times L \times N_p \times N_c) \times (T \times P + D) \text{ (cu)} \tag{5}$$

If costs are paid at the end of the year, then at the date of the purchase of the installation their present value is:

$$= \frac{\left(I^2_{\max} \times R_L \times L \times N_p \times N_c\right) \times (T \times P + D)}{(1 + i/100)} \text{ (cu)} \tag{6}$$

where

i is the discount rate, not including the effect of inflation, in %.

Similarly, the present value of energy costs during *N* years of operation, discounted to the date of purchase is:

$$CJ = (I^2_{\max} \times R_L \times L \times N_p \times N_c) \times (T \times P + D) \times \frac{Q}{(1 + i/100)} \text{ (cu)} \tag{7}$$

where

Q is a coefficient, taking into account the increase in load and loss load factor, the increase in cost of energy over *N* years and the discount rate:

$$Q = \sum_{n=1}^{N} \left(r^{n-1}\right) = \frac{1 - r^N}{1 - r} \tag{8}$$

$$r = \frac{(1 + a/100)^2 \times (1 + b/100) \times (1 + c/100)}{(1 + i/100)} \tag{9}$$

If $r = 1$, then $Q = N$ and

a is the increase in load per year, in %;

b is the increase in cost of energy per year, not including the effect of inflation, in %;

c is the increase in loss load factor per year, in %; *c* shall be selected such that the loss-load factor does not exceed 1 over the anticipated operational life of the installation.

Where a number of calculations involving different sizes of conductor are required, it is advantageous to express all the parameters excepting conductor current and resistance in one coefficient, F, where

$$F = N_p \times N_c \times (T \times P + D) \times \frac{Q}{(1 + i/100)} \text{ (cu/W)} \qquad (10)$$

The total cost is then given by:

$$CT = CI + I^2_{max} \times R_L \times L \times F \text{ (cu)} \qquad (11)$$

Formulae (7), (8) and (9) can be used to calculate the operational losses over the anticipated life, rather than the cost of the losses by setting $D = 0$, $P = 1$, $b = 0$ and $i = 0$. This would allow a direct comparison of the losses for a range of cable sizes.

5 Determination of economic conductor sizes

5.1 First approach: economic current range for each conductor in a series of sizes

All conductor sizes have an economic current range for given installation conditions. The upper and lower limits of the economic range for a given conductor size are given by:

$$\text{Lower limit of } I_{max} = \sqrt{\frac{CI - CI_1}{F \times L \times (R_{L1} - R_L)}} \text{ (A)} \qquad (12)$$

$$\text{Upper limit of } I_{max} = \sqrt{\frac{CI_2 - CI}{F \times L \times (R_L - R_{L2})}} \text{ (A)} \qquad (13)$$

where

CI is the installed cost of the length of cable whose conductor size is being considered, in cu;

R_L is the a.c. resistance per unit length of the conductor size being considered, in Ω/m;

CI_1 is the installed cost of the next smaller standard conductor, in cu;

R_{L1} is the a.c. resistance per unit length of next smaller standard conductor size, including the effect of λ_1 and λ_2;

CI_2 is the installed cost of the next larger standard conductor, in cu;

R_{L2} is the a.c. resistance per unit length of next larger standard conductor size, including the effect of λ_1 and λ_2.

NOTE 1 The upper and lower economic current limits of each conductor size may be tabulated and used to select the most economic size of conductor for a particular load.

NOTE 2 The upper economic current limit of one conductor size is the lower economic current limit for the next larger conductor size.

5.2 Second approach: economic conductor size for a given load

5.2.1 General equation

The economic conductor size, S_{ec} is the cross-section that minimizes the total cost function:

$$CT(S) = CI(S) + I^2_{max} \times R_L \times (S) \times L \times F \text{ (cu)} \qquad (14)$$

where $CI(S)$ and $R_L(S)$ are expressed as functions of the conductor cross-section S, see 5.2.2.