AC DC POWER CIRCUITS DESIGN BY MICROSYSTEM CRITERIA

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Abstract. Innovation in the residential and commercial LV distribution for the near future it is necessary to effectively implement the objectives of improvements of energy savings and renewable energy and further developments, such as DC distributions. Microsystem criteria in designing AC and DC power circuits consist in modeling their structure with components of smaller size, in grouping adequately the supplying loads, in adopting circuit with conductors in bunch, in loop or in rope designs. "Natural" parameters like steady and transient current density and load current moment density are introduced to support the configuration of circuits and the sizing of conductor cross-section area especially for DC circuits adopting nominal voltages lower than AC circuits.

Key words: Electrical Installations, Ecodesign, System Distributions, Circuit Selection and Size, AC DC Design Criteria

SYMBOLS

The main symbols are :

S,ρ	cable cross-sectional area and resistivity.
I_Z	cable current-carrying capacity: its values are tabulated or calculated by the empirical formula (simplification of the Cenelcom method [1]) $I_Z(S) = \alpha I_Z(1)\, S^b$, where: - $I_Z(1)$ is the current-carrying capacity of 1 mm^2 cross-sectional area dependent on the kind of cable, corrected by appropriate derating factors α; - *b* is a parameter equal to 0.625.
I_B	circuit design current
i_B	relative value I_B/I_Z, $i_B \leq 0.8$ NEC [2] and $i_B \leq 1$ IEC [3].
f_s	simultaneity factor
δ_B,δ_Z	cable *steady current S-density* related to the actual or design value I_B/S and the maximum admissible value I_Z/S respectively.
U_n	nominal voltage (line to line in AC three phase systems) (rms).
ε,ε_R	voltage-drop ΔU/U and its resistive component in p.u.
l_B	physical length of end loaded circuit or equivalent lever arm of a circuit of distributed loads .
M_B	load current moment as product $I_B\, l_B$ [A m] of the load I_B and the l_B length-"lever arm" from the supply.
μ_ε	cable *current moment μ-density* [Am/ mm^2] for an assigned ε, defining the maximum admissible value of the product $\delta_Z l_Z = \delta_B l_B = \mu_\varepsilon$.
PD	protective device.
I_n, I_m	PD rating current and instantaneous operating current.
I_F, I_k	fault current and short circuit current respectively.
δ_F,δ_K	cable *transient current T-density*: actual fault current value $\delta_F = I_F/S$ or I_k/S [A/mm^2] and admissible value $\delta_K = K/\sqrt{t}$ dependent on the assigned kind of cable and on the tripping time t of the protective device PD (IEC Std. [2] admits 5 s as limit value for adiabatic events).
ρ(T)	$\rho(T_Z) = \rho(20°C)\,[1+((T_Z-20)/230)]$, 230 is the zero resistance temperature value (234 for copper, 228 for aluminum), T_Z conductor operating temperature; for copper ρ(20°C) = 0.017241 Ωmm^2/m [4]
K	IEC constant value [$As^{1/2}$/ mm^2], dependent on the kind of cable and on its operating temperature T_Z; it takes account of the resistivity, temperature coefficient and heat capacity of the conductor material and the appropriate initial T_i and final T_f temperatures. For Ethylene–Propylene EP insulated cables, $T_{i=}$ $=T_Z = 90°C$, $T_f = 250°C$, K is 143 $As^{-1/2}/mm^2$ [3].
K^2S^2	admissible let-through energy (IEC) for the cable [3].

I INTRODUCTION: MECHANICAL ANALOGY

Present-day distribution systems for low voltage residential and commercial customers appear inadequate to comply with the improvements of energy savings and renewable energy adoption and to favor innovations such as local DC distributions, thereby opening new horizons.

A general criterion of designing power distributions is to structure the system based on a *micro system approach or ecodesign,* that permits satisfying local needs and specific quality performances of the actual power system. The system configuration has to facilitate and coordinate the implementation of smaller sizes of components, energy and costs saving, separate distributions and schemes for different categories of loads [5,6].

The most general case of circuit presents the scheme constituted by an insulated power cable supplying a load and derived from a proper protective device PD in a delivery point at the voltage U_n (Figure 1).

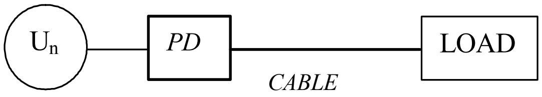

Figure 1 Three basic components of a circuit: supplied load, insulated power cable, PD protective device

The cabling and coordinated protection for each circuit at every system level must satisfy several conditions at the same time, in order to ensure a safe and reliable installation [10,11,12].

The protective device PD has to protect overcurrents: - overloads assuming its rating $I_B \leq I_n \leq i_B\, I_Z$, where i_B is the recommended reduction factor on the load current generally no higher than 0.8, regardless of the application of additional corrective factors α of the ampacity I_Z [2,3,6,8,14]; - fault currents I_F or short circuit currents I_k in transient events.

The electrical circuit can be analyzed and designed in a perfect analogy with a mechanical structure in relation to the internal forces characterizing the electrical behavior [6,8,9]. The mechanical design of a structural element considers its weight/load and its moment, product of the load and of its lever arms. In analogous way, the electrical design of a circuit has to model the size S of the conductor adequate to the electrical load I_B in normal condition. The sizing of the conductors cross section S has to satisfy the condition that the load current I_B of the circuit has to present with its length l_B (physical value) a moment $M_B= I_B\, l_B$ adequate to guarantee an assigned voltage drop ε. The simplest case, referred to the end-loaded condition, is the general case of a circuit supplying a single load I_B or a group load I_B as panel boards with moment M_B (Figure 2).

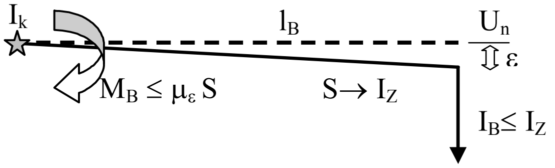

Figure 2 Analogy between a mechanical end loaded structure and an electrical basic circuit of a single load

The cases of circuits with distributed loads I_{Bj} at the proper length l_{Bj} (Figure 3 scheme (a)) are generally typical of a single line final circuit with total moment ΣM_{Bj} of its loads calculated as $\Sigma I_{Bj}l_{Bj}$. Let's note that the moment M_B value is indifferent whether the load is single (concentrated) or distributed, while it is necessary that the single load moment $I_B\, l_B$ or the loads total moment $\Sigma I_{Bj}l_{Bj}$ have the same value M_B.

This is the way to introduce the equivalence that allows to reducing a circuit with distributed loads I_{Bj} to the basic design of an end loaded circuit with a single load equal to the total current $I_B=\Sigma I_{Bj}$.

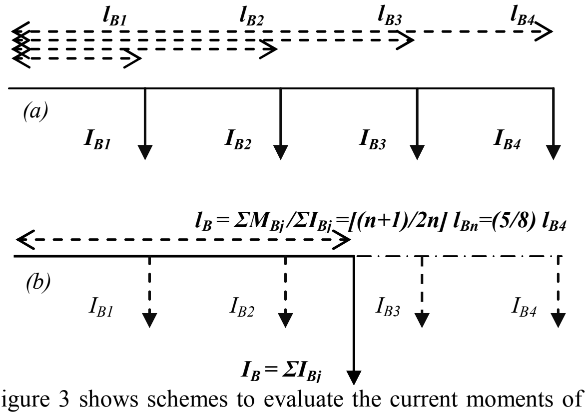

Figure 3 shows schemes to evaluate the current moments of a single line circuit: the scheme (a) of uniformly distributed n (=4) equal loads I_{Bj} from the start point and their length l_{Bj}; the equivalent scheme (b) of total current $I_B=\Sigma I_{Bj}$ applied at the equivalent length of lever arm $l_B=\Sigma M_{Bj}/\Sigma I_{Bj}$.

A rule of thumb to evaluate the total moment M_B in circuits with distributed loads I_{Bj} (Figure 3) is to calculate it as the moment of the total current $I_B=\Sigma I_{Bj}$ applied at the equivalent length of lever arm $l_B=\Sigma M_{Bj}/\Sigma I_B=c\, l_{Bn}$, being l_{Bn} the circuit length of the farthest load l_{lastjB}

$$M_B=\Sigma M_{Bj}=\Sigma I_{Bj}l_{Bj}=I_Bl_B=I_B\, c\, l_{Bn}. \qquad (1)$$

assuming for the factor $c=l_B/l_{Bn}$ a value adequate to the effective loads distribution. Practically cautious values are ranging from 0.7 to 1 (end loaded circuit). For n equal loads I_{Bj} uniformly distributed at distances $l_{Bj}=jl_{Bn}/n$ from the start point of the circuit, the factor c is computable as $c=(n+1)/2n$. Let's note that for a circuit of distributed loads with the total length of the last load $l_{Bn}.= l_{lastB}$, the l_B that has to considered in the moment evaluation is the equivalent length of lever arm equal to $l_B = c\, l_{Bn}$.

II THE NATURAL PARAMETERS: THE COORDINATION TRIANGLE

The paper highlights the three "natural" parameters that characterize intrinsically the conductor size of the circuit in correlation to the kind of the power cable, to the load and to the duty of the protective device. They are the steady current density $\delta_B= I_B/S$, the transient current density $\delta_k= I_k/S$ and the load current moment density $\mu_\varepsilon= M_B/S$ that constitute the variables of the coordination triangle of an electrical circuit (Figure 4).

The natural parameters are introduced to correlate directly the conductor cross-section S area of a circuit in AC and DC systems to the I_B, I_k and M_B (or l_B) of the same circuit.

It is shown in the next paragraph how the natural parameters δ_B, δ_k, μ_ε depend on "*intrinsic factors*" such as the material constitution of the conductors (ρ), the cable insulation (K, T_Z, I_Z), the protective device (tripping time t) , the layout and parameters of the circuit (ε, l_B, λ, U_n), characteristics of the load ($\cos\varphi$, f_s).

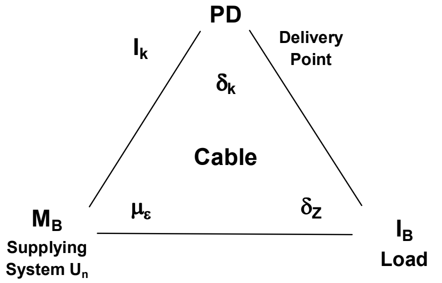

Figure 4 The circuit has to satisfy the *coordination triangle*: the PD-cable system has to be adequate to the load, the overcurrents and the load moment

The steady S-density δ_Z .The conductor size S of the circuit has to have in normal conditions the thermal withstand capability of carrying steadily the load current I_B and satisfy

$$\delta_Z S = I_Z \ge I_B/i_B \qquad (2)$$

that is the S area has to have the ampacity I_Z, being $\delta_Z=I_Z/S$ the *admissible steady current density (S-density)* δ_Z.

The steady density δ_Z of the area S can be expressed as the ratio related to the known density δ_{Zr} of a reference area S_r using the empirical formula obtained by a simplification of the Cenelcom method [1]

$$\frac{\delta_Z}{\delta_{Zr}} = \left(\frac{S_r}{S}\right)^{(1-b)} \qquad (3)$$

Let's note that: - if the reference area S_r is assumed equal to S_r=1 mm^2, the δ_{Zr} is coincident with its current-carrying capacity $I_Z(S=1)$; - the δ_Z is a parameter that increases with the reduction of the cross-section area S (Figure 5), so the relevance of circuits configurations that promote cable cross sections of smaller size is evident. The empirical formula is applicable to the conditions of steady-state operation of cables not buried at voltages up to 1.2 kV.

It is well known that the steady heat transfer which depends on cable geometry and its surroundings, is proportional to the superficial longitudinal area A of the conductor (if cylindrical with r radius, A is equal to A=2πr per a meter of length), therefore the density $\delta_Z(S)$, ratio between the ampacity I_Z and the related cross section area ($S=\pi r^2$), increases with the decreasing of the cross section S.

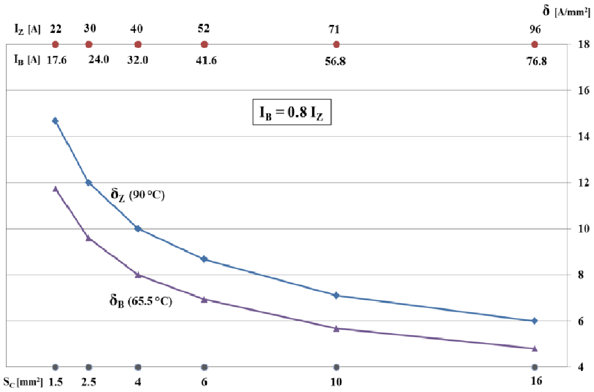

Figure 5 Assuming I_B=0.8I_Z it shows for copper 2 conductors, EP insulated power cables the current densities profiles δ_Z(90°C), δ_B(65.5°C) versus the cross-section areas [mm^2] in a range of commercial values S_c (1.5; 2.5;4;6;10;16 mm^2) suitable for final circuits

The transient T-density δ_K. On the other hand, the definable transient current density δ_K, ratio between the maximum admissible overcurrent and the cross section area S of the conductor in coordination with an assigned PD tripping time, has a value invariant with the cross-section area S, being related to a transient adiabatic heating by a guaranteed timely protection.

The cable conductors, according to their kind and size, must tolerate a defined prospective let-through energy in the PD tripping time t [3], that is must have a thermal withstand capability no lower than the short-circuit current during the PD tripping time t. The formula (see table 240.92(B) NEC [2]):

$$(I_k^2 / S^2)\, t \le K^2 \qquad (4)$$

shows that it could be defined the *admissible transient or adiabatic T-density* δ_K [A/mm^2] and the *admissible short-circuit current I_k for the conductor related to the t time:*

$$I_k \le (K/\sqrt{t})\, S = \delta_K S \qquad (5)$$

This expression (5) allows: - defining the term $K/\sqrt{t}$ as a parameter δ_K dependent on the assigned kind of cable and on the tripping time of the protective device PD; - verifying $\delta_K S \ge I_k$ that is the adequacy $\delta_K S$ of the conductor S to be derived in the designed point of the system characterized by an actual short circuit current I_k.

Let's note that if the PD tripping time is equal to t=1s, the δ_K value is the same as the K value.

DC distributions can favor the adoption of PVC insulated cable considering that their circuits are generally characterized by limited fault currents during fault conditions [14] within values comparable with the circuit nominal currents.

The moment μ-density μ_ε The design of each circuit has to arrange the supplying distribution of a length l_B with a moment $M_B = I_B\, l_B$ adequate to guarantee the assigned voltage drop ε supplying the load I_B.

In AC final circuits and in DC circuits the voltage-drop ε is equal to the resistive component ε_R: in the other AC circuit the ε could be considered approximately equal to ε_R.

Assuming the resistivity ρ always is approximately equal to $\rho=\rho_Z=\rho(T_Z)$, in reference to the well-known voltage drop formula [8,9,15], it can be defined that the *maximum moment μ-density* μ_ε [Am/mm^2]:

$$\mu_\varepsilon = \varepsilon\, U_n / \rho\, \lambda \cos\varphi \ge M_B/S = \delta_B\, l_B \qquad (6)$$

Where in DC systems, cosφ=1 and λ = 2 and in AC three phase systems: a) for three phase circuits, it has to be assumed $\lambda=\sqrt{3}$; b) for single-phase circuits $\lambda = [1+(S_{line}/S_{neutral})]\sqrt{3}$ or $\lambda = 2\sqrt{3}$, if $S_{neutral} = S_{line}$.

The expression (6) highlights that the parameter μ_ε is dependent on standardized data of the supplying system (ε, U_n, ρ, λ, cosφ). As example, (Figure 6) for a single-phase DC

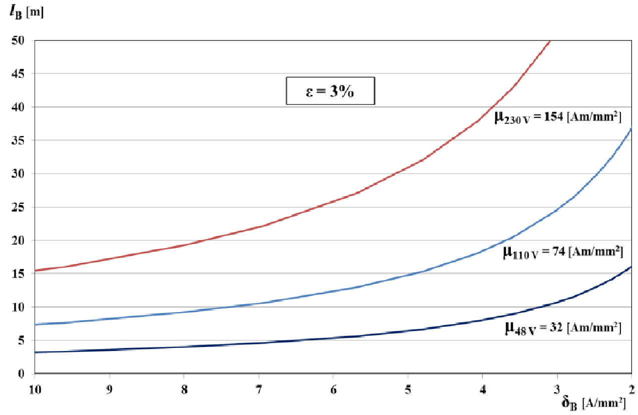

Figure 6 In reference to EP insulated copper cables, assuming ε= 0.03 and cosφ=1, the figure shows the profiles of the prospective lever arm l_B versus the current density δ_B for the three voltages 230,110,48 V and the correlated μ_ε values.

circuit of assigned $\varepsilon = 0.03$, at the worst value U_n=48V, if I_B=6,10 and 16A (300,500 and 800 W) adopting an EP insulated cable of cross sectional area S=2.5 mm^2 the actual $\delta_B = I_B/S$ is 2.4; 4.0; 6.4 A/mm^2 respectively and the l_B has to be no longer than the equivalent lever arm $l_B \leq \mu_\varepsilon/\delta_B = \mu_\varepsilon S/I_B$= 13.3;.8; 5m to guarantee $\varepsilon \leq 0.03$.

The (6) can be rewritten as

$$\mu_\varepsilon S \geq M_B = I_B l_B \qquad (7)$$

that has an operational value in defining the cross-sectional S that will satisfy the assigned voltage drop.

In conclusion, the intrinsic factors (ρ, K, T_Z, I_Z, t, ε, l_B, λ, U_n, $\cos\varphi$) define the natural parameters δ_B, δ_K and μ_ε of a circuit (PD-cable system) independently from the actual values of the I_B, I_k, M_B of the circuit specific case.

In general if the three parameters are not coordinated, the S value to be adopted is the higher than that is required to satisfy the I_B , I_k or M_B.

Indeed the triad of parameters δ_B, δ_k, μ_ε and the parameters I_B, I_k, M_B of a specific circuit are naturally correlated by a same value of a cross section S defined by the parity equation

$$S = I_B/\delta_B = I_k/\delta_K = M_B/\mu_\varepsilon \qquad (8)$$

It is possible to coordinate the circuit design in reference to the load current I_B; in a micro system approach the smaller size of conductors that can be selected results the cross section value of the commercial series S correlated to the ampacity equal or rounded up to the value $I_Z = I_B/i_B = I_B/0.8$.

So that the layout of the distribution system can remain defined "naturally" correlated to the smaller size S if the actual required lever arm l_B of the circuit makes a moment

$$\mu_\varepsilon S \geq M_B = I_B l_B \qquad (9)$$

that is the needed circuit length or equivalent length l_B (Figure 5) satisfies the expression (9).

To complete the coordination, it has to be verified that the system point of the circuit derivation is characterized by a short circuit current

$$\delta_K S \geq I_k \qquad (10)$$

If the cross-section area $S(I_B)$ is not sufficient to satisfy the condition (9), instead of rising the same value S of the circuit the microsystem approach suggests to reduce the moment value M_B decreasing the circuit design current I_B and/or re-arranging the layout of the circuit in its configuration, as shown in the following paragraph.

IV. CONFIGURATION CRITERIA. CIRCUITS IN BUNCH, LOOP AND ROPE DESIGNS

Generally the size S of the conductors in a given circuit is assumed equal for all the circuit length and arms. A size variability has to be avoided because it constitutes a complexity for the circuits installation and maintenance. In any case, the PD rating I_n has to be coordinated with the weak value of S_w in the circuit ($I_B \leq I_n \leq i_B I_Z$ (S_w)). Otherwise adopting few cabling sizes in a distribution system has a significant impact on the global cost reduction, the wiring installation time and on the operational efficiency.

One of the major goals is to locate the power source node in the electrical center of the served loads area especially for d.c. circuits with nominal voltages lower than the a.c. circuits. A barycentered distribution configuration allows selection of either reduced voltage-drop and losses, or at the assigned voltage-drop, a reduced volume of conductors by the adoption of smaller cable cross sections.

The expression (6) $\mu_\varepsilon \geq \delta_B l_B$ contributes to define the loads area extensions around the supplying switchboards that guarantee assigned ε values. In fact, the product $\delta_B l_B \leq \mu_\varepsilon$ highlights that the distribution centered in a load area promotes shorter lengths l_B and higher current densities δ_B. For DC distribution it appears recommendable to adopt low values of circuit design current I_B adequate to presumable low value of U_n such as 48V.

A circuit with distributed loads I_{Bj} can be constituted by a single line design or also by a tree design with a common trunk that taps more (h-)arms supplying distributed (j-)loads (Figure 7) [6,8,9].

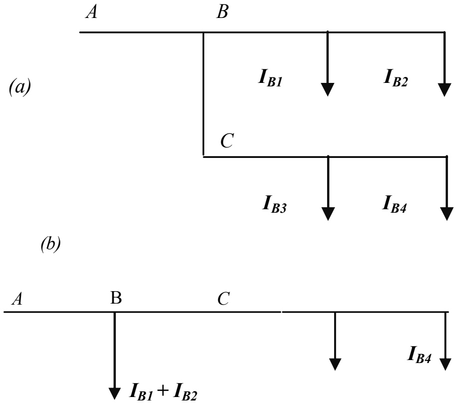

Figure 7 shows in the upper position a circuit constituted by h=2 arms supplying j=4 loads in a tree design with a first common trunk AB. Its single line equivalent scheme is constituted by the arm (BC,3,4), if assumed of heavier moment, and considering for the arm (B,1,2) the contribution of its partial load group on the common trunk AB equal to I_{B1} +I_{B2} applied in B. When AB=0 the circuit with two arms by the same PD changes in a bunch design.

The maximum voltage drop is defined by the worst value of the load current moment from the electrical service that appears on the arm with the farther/heavier loads of equipment served, considering their simultaneity factors f_s.

For a circuit of a single line or tree design with distributed loads I_{Bj}, the selected conductor size $S(I_Z)$ assures the voltage drop ε, if the moment of the total current $I_B = \Sigma I_{Bj} \leq i_B I_Z$ applied at the equivalent length of lever arm l_B=c l_{Bn}, satisfies the already mentioned condition (7)

$$\mu_\varepsilon S(I_Z) \geq M_B = (\Sigma I_{Bj})\ c\ l_{Bn} \qquad (11)$$

In the cases that the cross-section area $S(I_Z)$ is not sufficient to satisfy condition (11), instead of rising the same value S of the circuit the microsystem approach suggests to preserve the moment M_B on low values :

- reducing the circuit design current I_B such as from 20A-16 A to 10 A - 6 A especially for DC circuit at

U_n=48V for which power values of 500, 300 W can be sufficient,

- re-arranging the layout of the circuit in its configuration, avoiding to adopt for the circuit the tree design or a single line for many loads.

An useful criterion in circuit design suggests avoiding configurations with complex tree design considering that the tree design needs :

- a widespread use of electrical taps, introducing potential hazardous hot points,
- composite configurations introducing an avoidable escalation of loads moment.

A method to decrease the current moment and so the voltage drop of a circuit of assigned load current I_B is the revision of number of lines/conductors, derived from the same protective device, in a design open (*in bunch)* or closed *(in loop or in rope)*.

Figure 8 shows in the sample schemes (a) and (b) the cases of bunch and loop circuits respectively where the n (=4) equal loads I_{Bj} (=2.5A) are distributed properly or alternatively on the two lines at their lengths $l_{Bj}=jl_{Bn}/n$ from the PD (being l_{B4}=20m that is not the equivalent lever arm and making reference to an U_n = 48V).

The bunch or loop circuits have to eliminate the common trunks of a tree design.

The bunch design allows arranging a same circuit with m=2 or 3 lines supplied in a barycentered way among the loads by a same PD rated in reference to $I_B ==\Sigma I_{Bj}$..

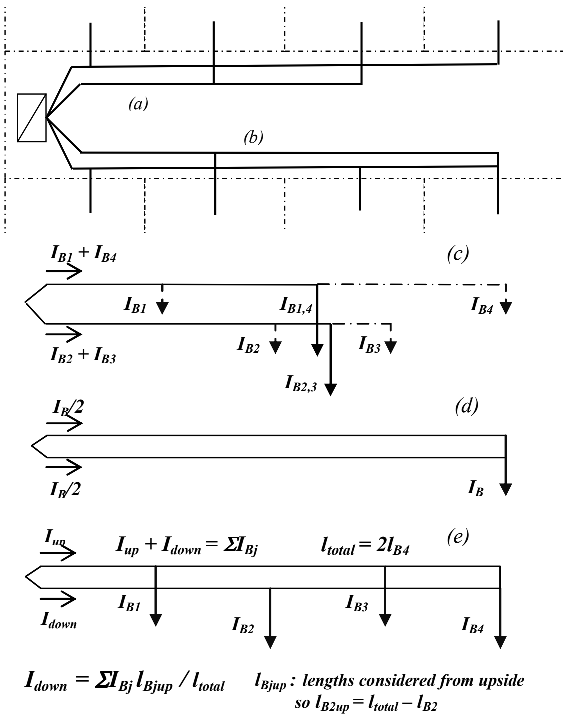

Figure 8 shows a circuit with a bunch design of m=2 lines in (a) and (c) ; with a loop design in (b) and (e): the scheme (d) shows the case of a loop for an individual load supplied by two parallel conductors (circuit in rope design.)

The loop circuit, figure 8 (b) and (e) with $l_{total}=2l_{B4}$ (=40m) allows supplying the distributed loads by two routes from the same PD, that is, from the same source (the two routes run together). The total current $I_B =\Sigma I_{Bj}$ (=10A) is divided in I_{up} and I_{down} that in analogy to the mechanical design can be considered as load currents "reactions". The loop (Figure 9) could be studied like two radial circuits with the current rate I_{up} (5.6 A) and I_{down} (4.4 A) respectively, connected in their end point and supplied by a same PD rated in reference to $I_B = I_{up} + I_{down}$. The loop presents the same current moment on the two arms up and down. To highlight a rule of thumb let's consider a single load I_B supplied by a radial circuit (Figure 8d) of the cross section S with the length l_B, in this case its current moment is equal to $M_B=I_B\, l_B$. It is relevant to note that the single load I_B supplied by a loop and located in a variable position l_{up} and l_{down} long its length $2\, l_B = l_{up}+l_{down}$, determines a moment M_{Bloop} in the two arms that assumes the same value equal to

$$M_{Bloop}= I_B\, l_{up} l_{down}/2\, l_B \qquad (12)$$

When $l_{up}=l_{down}=l_B$ (factor c=1) the loop design is effectively a rope (parallel) design, the moment (12) is $M_{Bloop}=I_B\, l_B/2$. In this case the M_{Bloop} assumes a half value of the moment of the radial circuit l_B, while in all the other cases of $l_{up} \neq l_{down}$ the moment value is cautiously lower than $I_B\, l_B /2$.

In these bunch and loop configurations m-taps (2 or 3) are

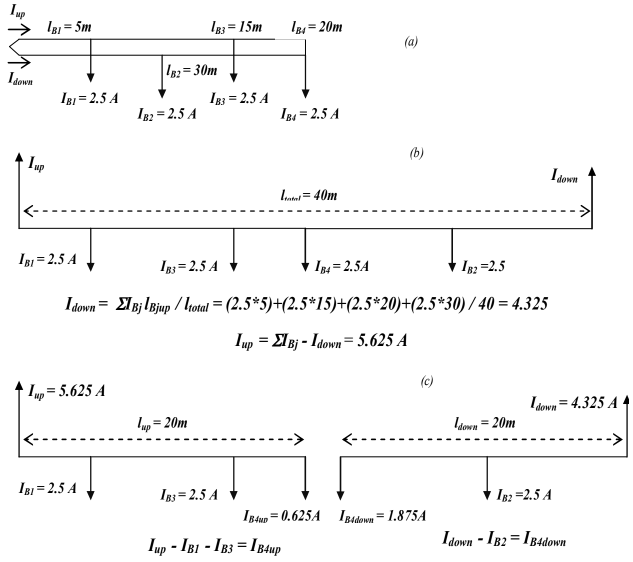

Figure 9 shows the case of a loop for 4 loads in (a). The total current $I_B =\Sigma I_{Bj}$ (=10A) is divided in I_{up} and I_{down} that in analogy to the mechanical design can be considered as load currents "reactions". Being $I_{up}+I_{down}=I_B$ a first condition, the I_{up} and I_{down} values can be obtained by considering their reaction moment. I_{down} can be evaluated by I_{down} * l_{total} $=\Sigma I_{Bj} l_{Bjup}$(=175Am) with the lengths l_{Bjup} referred to the upside (note l_{B2up}=30m).

The loop is studied like two radial circuits obtained cutting the loop in that point X where the derived load I_{BX} (I_{B4}) is supplied simultaneously by I_{up} and I_{down}, and so to be divided in two contributes (I_{B4up}=0.625A and I_{B4down}=1.875A) respectively as it's shown in (c).

concentrated at the start point of the circuit at the PD terminals, easier to inspect. Moreover the taps widespread along each line will have reduced mean values of current.

In conclusion a method to decrease the current moment for the cases of circuits with distributed loads (n-loads) adopting more conductors mS (i.e. m=2) the condition (11) can be verified for each one of the m-arms:

- *in a bunch design* , useful specially for continuous loads (such as generally lights $f_s=1$ and I_{Bj}=constant value), the moment M_B to be considered is the maximum partial value among the m moments $M_{Bh}=\Sigma I_{Bj}l_{Bj}$ (i.e. for the schemes (c) in figure 8 the maximum value between $M_{B1,4}= I_{B1}l_{B1}+ I_{B4}l_{B4}$ and $M_{B2,3} = I_{B2}l_{B2}+ I_{B3}l_{B3}$).
- *in a loop design*, useful specially for no continuous loads ($f_s<1$, I_{Bj}=variable value, $\Sigma I_{Bj}\leq I_B$), for each loads set, the moment M_B is valuable on one arm of the loop (scheme (d) of figure 8 and scheme c of figure 9, $M_{B2,4}=I_{B2}l_{B2}+I_{B4down}l_{B4}$= 2.5x10+1.875x20 =62.5Am or $M_{B1,3,4up}$=62.5Am).

For the cases of end loaded circuits with a load or a loads group (factor c=1), to decrease the current moment other than increasing the cross-sectional areas in the commercial series, the micro system approach suggests to increase the area by adopting more (m=2 or 3) conductors S in rope design (in parallel), which may offer the opportunity to adopt a resultant mS size not included in the commercial series, reducing the total volume of conductors.

In reference to the previous examples, being μ_ε (ε=0.03)= 32 Am/ mm^2, I_B =10 A , if the layout of the circuit requires an actual length - lever arm l_B up to 16 m. Instead of adopting a cross sectional area of S= 6 mm^2, a rope design of two S= 2.5 mm^2 in parallel makes admissible a l_B length up to $l_B\leq\mu_\varepsilon S/I_B$=16m with lower volume of copper.

For conductors connected in parallel the IEC standard 60364 [3] requires that they have no final circuits along the length, but does not impose limits to the minimum size as the NEC standard [2] that requires a value no lower than 1/0 AWG ($\cong$50 mm^2) (art.310.4).

In the IEC approach for lower sizes the conductor areas follow the series $\sqrt[5]{10}$ and so 1.5, 2.5,4,6,10, 16 mm^2; for m=2 it is possible to obtain outside of this series 3,5,8,12,20,32 mm^2 and so on. Let's consider that the formula CENELCOM can assist the definition of the total ampacity $I_Z(mS)$ as $I_Z(mS)\cong\alpha I_Z(1)(mS)^b$.

V. CONCLUSIONS: WHAT INNOVATIONS WITHOUT CHANGES ?

A new cultural education is needed for actual safety progress and an effective microsystem approach while pursuing goals on energy and costs saving [5,6, 8, 9, 16, 17].

Operational parameters like steady and transient current density δ_Z, δ_k and load current moment density μ_ε are introduced to analyze the influence of the conductor cross-section area in the circuit sizing especially for DC circuits adopting nominal voltages lower than AC circuits. Worldwide integrated solutions are requested as: -adequate revised values of circuit design current I_B especially for DC distributions; - solutions of local DC conversions and distributions, opening new horizons – an analysis of the feasibility of a new series of commercial cross section areas of the power cables and of new rating values of circuit breakers promoting the reduction of the conductors volume.

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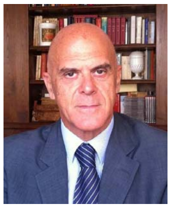

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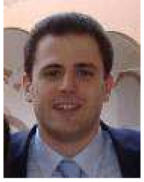

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