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An Effective Cable Sizing Procedure Model for Industries and Commerial Buildings

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ABSTRACT

This paper mainly focuses on the cable sizing methods and calculation of electrical cables according to the various international standards. For instance, International Electrotechnical Commission (IEC), National Electrical Code (NEC), British Standard (BS) and Institute of Electrical and Electronics Engineers (IEEE). The basic philosophy underlying any cable sizing calculations are the same. The main objective of this research work is to develop effective cable sizing model for building services.

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1. INTRODUCTION

There are four primary reasons that the cable sizing is very important at design stage. First and foremost, cable sizing is important to function endlessly under full load condition exclusive of being damaged. Moreover, it is necessary to hold up the worst short circuit current flow and ensure that the protective devices are effective during an earth fault. Ensure that, the supply to the load with a suitable voltage and avoid excessive voltage drops.

2. CABLE SELECTION, SIZING AND OTHER PARAMETERS

Sizing Cable sizing methods follow the unchanged basic step process. Firstly, it’s vital to gather data about the cables, installation surroundings, and the load that it will carry. In addition, it’s crucial to find the current carrying capacity (A, ampere) and voltage drop per ampere meter (mV/A/m) of the cable [1]. The current carrying capacity of a cable is the maximum current that can flow continuously through a cable without damaging the cable's insulation and other components [2]. Short circuit temperature rise and earth fault loop impedance are significant factors to verify the cable size.

Each conductors and cables except superconductor have some amount of resistance. This resistance is directly proportional to the length and inversely proportional to the diameter of the conductor.

$$R \propto L/a \quad [\text{Laws of resistance } R = \rho\,(L/a)] \qquad [1]$$

Voltage drop occurs in every conductor as the current flows through it. According to Institute of Electrical and Electronics Engineers (IEEE) rule B-23, at any point between a power supply terminal and installation, voltage drop should not increase above 2.5% of provided (supply) voltage [3].

The cable should withstand the temperature and heat emmisionwith using good insulation materials such as conductors, and bedding. Table 1 shows the current carried by any conductor for continuous periods during normal operation shall be such that the suitable temperature limits.

Table 1. Maximum operating temperatures for types of cable insulation

Type of insulation	**Temperature limit**
Thermoplastic	70°C at the conductor
Thermosetting	90°C at the conductor
Mineral	70°C at the sheath and more

Cables with larger cross-sectional areas have minor resistive losses. Bigger cable able to dissipate the heat better than smaller one. Hence a 15 mm^2 cable will have a higher current carrying capacity than a 4 mm^2 cable. Table 2 explains the difference between current carrying capacity of 16 mm^2 and 25mm^2.

Table 2. Current carrying capacity and voltage drop of different types of cable size [4]

Cable size	Current-carrying capacity	Voltage drop
$\leq$16mm^2	0.95	1.10
$\geq$25mm^2	0.97	1.06

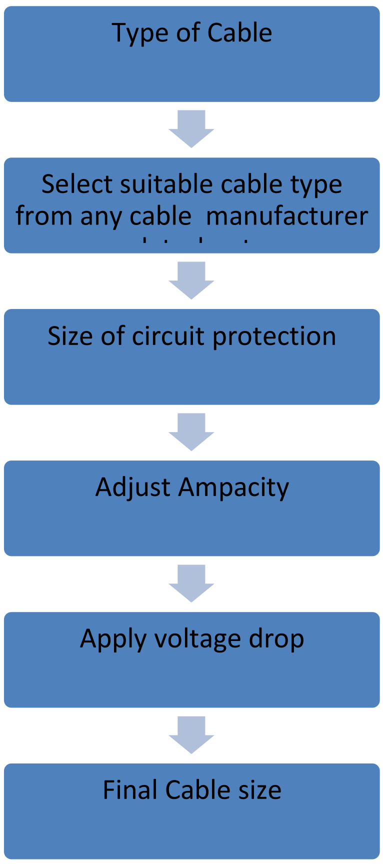

Figure 1. Flow chart shows the steps to determine the cable sizing and voltage drop

3. CABLE SELECTION SIZING FORMULAION

International standards and cable manufacturers will provide derating factors for a range of installation conditions, for example ambientor soil temperature, grouping or bunching of cables, and soil thermal resistivity. The installed current rating is calculated by multiplying the base current rating with each of the derating factors.

$$I_c = I_b \times k_d \quad [2]$$

Where I_c is the installed current rating (A), I_b is the base current rating (A) and K_d are the product of all the derating factors.

Upstream protective device circuit breaker is not required to protect the cable against overloads. As a result, cables need only to be sized to cater for the full load current of the motor [5].

$$I_l \leq I_c \quad [3]$$

Where I_l is the full load current (A), I_p is the protective device rating (A) I_c is the installed cable current rating (A).

Cable Impedances is a function of the cable size (cross-sectional area) and the length of the cable. Most cable manufacturers will quote a cable's resistance and reactance in Ω/km. The following typical cable impedances for low voltage AC single core and multicore cables can be used in the absence of any other data [6].

For single circuit

$$I_t \geq \frac{I_n}{C_a C_s C_d C_i C_f C_c} \quad [4]$$

Where the protective device is is a semi enclosed fuse to BS 3036, C_f=0.725 otherwise C_f=1. The cable installation method is 'in a duct in the ground' or 'buried direct', C_c= 0.9. For cables installed above ground C_c= 1. C_a= Ambient temperature, C_s= Soil resistivity, C_d=dept of burial, Ci= Thermal Insulation, I_b= the design of current of circuit, I_t= the value of current for ingle circuit at ambient temperature. For cables installed above ground C_s and C_d =1.

For group

$$I_t \geq \frac{1}{C_a C_s C_d C_i}\sqrt{\left(\frac{I_n}{C_f C_c}\right)^2 + 0.48\, I_b^{\,2}\left(\frac{1-C_g^{\,2}}{C_g^{\,2}}\right)} \quad [5]$$

For cables having cross sectional area 16mm^2 or less, the design value of mV/A/m is obtained by multiplying the tabulated value by factor C_t given by:

$$C_t = \frac{230 + t_p - \left(C_a^{\,2} C_g^{\,2} C_s^{\,2} C_d^{\,2} - \frac{I_b^{\,2}}{I_t^{\,2}}\right)(t_p - 30)}{230 + t_p} \quad [6]$$

For AC three phase system

$$V_{3\phi} = \frac{\sqrt{3} I (R_c \cos\phi + X_c \sin\phi) L}{1000} \quad [7]$$

Where $V_{3ø}$ is the three phase voltage drop (V), I is the nominal full load or starting current as applicable (A), R_c is the ac resistance of the cable (Ω/km), X_c is the ac reactance of the cable (Ω/km) cos ø is the load power factor (pu) L is the length of the cable (m) [7].

For AC single phase system

$$V_{1o} = \frac{2I(R_c \cos\phi + X_c \sin\phi)L}{1000} \quad [8]$$

It is standards to indicate maximum permissible voltage drops, which is the maximum voltage drop that is permissible across a cable. If the cable exceeds this voltage drop, then a bigger cable size should be preferred.

Greatest voltage drops across a cable are specified because load consumers will have an input voltage tolerance range. If the voltage at the electrical device is lower than its rated minimum voltage, then the appliance may not work appropriately [8].

It may be more precise to calculate the maximum length of a cable for a particular conductor size given a maximum permissible voltage drop 5% of nominal voltage at full load rather than the voltage drop itself. To construct tables showing the maximum lengths corresponding to different cable sizes in order to speed up the selection of similar type cables.

For a three phase system

$$L_{max} = \frac{1000V_{3o}}{\sqrt{3}I(R_c \cos\phi + X_c \sin\phi)} \quad [9]$$

For a single phase system

Table 3. Shows the percentage of low voltage installation supplied voltage

	Lighting	Other Uses
Low voltage installation supplied directly from a public low voltage distribution system	3%	5%
Low voltage installation supplied from private LV supply (*)	6%	8%

$$L_{max} = \frac{1000V_{Lo}}{2I(R_c \cos\phi + X_c \sin\phi)} \quad [10]$$

A high amount of current will flow through a cable for a short time when there is short circuit happens in the circuit. This surge in current flow causes a temperature rise within the cable.

High temperatures can trigger unnecessary reactions in the cable insulation, sheath materials and other components, which can degrade the condition of the cable. Bigger cable cross-sectional area can dissipate higher fault currents. Therefore, cables should be sized to withstand the largest short circuit.

The minimum cable size due to short circuit temperature rise is typically calculated with an equation of the form:

$$A - \frac{\sqrt{i^2 t}}{k} \quad [11]$$

The temperature rise constant is calculated based on the material properties of the conductor and the initial and final conductor temperatures as per equation 12.

$$k = 226\sqrt{\ln\left(1 + \frac{\theta_f - \theta i}{234.5 + \theta_i}\right)} \quad [12]$$

Figure 2 shows rating factors to be included for more than one circuit and cables buried directly in the ground with cable- to cable clearance (α).

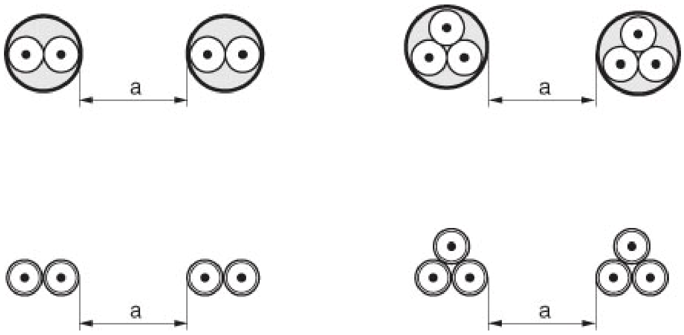

Figure 2. Reduction factors for more than one circuit, single-core or multi-core cables laid directly in the ground.

4. RESULTS

Table 4. Voltage drop for different Electrical Components

Number of circuits	Cable to cable clearance (a)[a]				
	Nil (cables touching)	One cable diameter	0.125 m	0.25 m	0.5 m
2	0.75	0.80	0.85	0.90	0.90
3	0.65	0.70	0.75	0.80	0.85
4	0.60	0.60	0.70	0.75	0.80
5	0.55	0.55	0.65	0.70	0.80
6	0.50	0.55	0.60	0.70	0.80

Table 5. Sample of calculation of voltage drop using V=IR

NO	DESCRIPTION		MAX DIST	POWER	LOAD	VOLT	CURRENT	CSA	mV/A/m	DROP		REMAIN VOLT
	FROM	TO	(m)	(W)	(W)	(V)	(A)	(mm2)		(%)	(v)	
1	DB	Light	10	42	84	240	0.35	2.5	18	0.2	0.38	239.63

Table 5 explains the voltage drop between the origin of an installation and any load point should be greater than the values in the table below expressed with respect to the value of the nominal voltage of installation. Table 6 shows a sample of calculation method to calculate the voltage drop.

The voltage drop for any particular cable run must be voltage drop does not exceed 2.5% of the nominal voltage. The nominal voltage drop should be not more than 2.5% voltage from main switch board to any point of installation.

5. CONCLUSION

Selecting power cable and types of cables with the sizing of the conductors for specific applications is a very essential part of the plan of any electrical system. This task that is often performed with a least amount of effort and with minimum reflection for all of the applicable design issues. The consequential catastrophe is that inappropriate selection and sizing can easily amplify the installed cost of a facility while also dropping the reliability of the complete system.This paper highlights on some of the considerations that should be practice for cable selection each and every time. It then suggests the right design tool to calculate and facilitate the selection process without resorting to simplifications.

Nomenclature

Parametes and constraints

I_c : Installed current rating (A)
I_b : Base current rating (A)
K_d : Product of all the derating factors
I_l : Full load current (A)
I_p : Protective device rating (A)
C_c : Circuit buried in the ground
C_a: Ambient temperature
C_s: Soil resistivity
C_d : Depth of burial
C_i : Thermal Insulation
I_t: The value of current for ingle circuit at ambient temperature
C_f : Semi-enclosed fuse to BS 3036
C_g: For grouping
$V_{3ø}$: Three phase voltage drop (V)
I: current (A)
R_c: AC resistance of the cable (Ω/km)
X_c: AC reactance of the cable (Ω/km)
cos ø: Load power factor (pu)
L: Length of the cable (m)
A: Short circuit temperature rise
k: Cable material properties
θ_f: Final conductor temperature
θ_i: Initial conductor temperature
α: cable- to cable clearance

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