1 Objective

Document the criteria used in the calculation and selection of the nominal conductor size for the circuit 01-MOT-05-F, that operates at 480.00 volts and 60 Hz.

2 Scope

This technical calculation report describes the criteria used to compute and select the conductor size for a Motor based on the allowable ampacity, voltage drop under normal operation, maximum voltage drop during motor starting and thermal efforts during short-circuit conditions.

Conductors selected for the circuit are made of Copper with XHHW_2 insulation and with a maximum operating temperature of 75.00 ℃. The criteria applicable for conductor selection will be from NFPA-70-2020 (NEC)©

3 General data used

The information listed below describes the criteria used for the conductor nominal size selection.

Field	Value
System rated voltage	480.00 V.
Ambient Temperature	40.00 ℃
Conductor Material	Copper
Insulation Type	XHHW_2
Conductor Maximum Operation Temperature	75.00 ℃
Maximum Voltage Drop percentage allowed for the circuit	3.00 %
Maximum Voltage Drop percentage allowed in the circuit during the motor-starting	15.00 %

4 Information of the circuit for conductor size selection

The data listed below was used for the calculation procedures in the nominal conductor size selection:

Field	Value
System	Alternating Current
Load Type	Motor
Power	100.00 HP
Equipment Rated Voltage	500.00 V
Number of Phases	3
Number of wires	3
System Power Factor (PF.)	0.8600
Efficiency	0.9250
Demand Factor	1.0000

Field	Value
Circuit Length	125 m
Conductor Type	Multiconductor
Termination Temperature	75 ℃
Install. System (Raceway/Cable tray/Duct)	Duct
Material of the Raceway/Cable tray/Duct	Aluminum
Starting Power Factor	0.3100
Installation Detail	Detail 1
Short-circuit current	23.00 kA
Failure time	3.00 Cycles
Max. conductor instantaneous elevation temp.	250 ℃

5 Selection of the conductor size

5.1 Using 1 conductor per phase

5.1.1 Ampacity conductor size selection

The value of the rated current is calculated using the following equation:

$$IN = \frac{P \cdot 746}{\sqrt{3} \cdot V \cdot FP \cdot Eff}$$

Where:

Ir	Rated Current [Amp].
P	Motor Rated power [HP].
V	Nominal Voltage [Volts].
PF	Power Factor.
Eff	Efficiency.

Feeder rated power is used to compute the rated current. Obtaining a value of 108.28 Amps.

In accordance with section 430-22 the circuit conductor ampacity should not be less than (125.00%In). Thus the selected conductor ampacity should be at least 135.36 Amperes.

For installation in low voltage buried ducts, the correction factor for ambient temperature is considered to be 1.0. The correction factor for variations in ground temperature will be determined later by Ft (Adjustment Factor for ground temperature).

It is considered that the conductor is installed in Duct, thus the conductor allowable current should not exceed the ampacity indicated in the "Table B.310.15(B)(2)(6) Ampacities of Three Insulated Conductors, Rated 0 through 2000 Volts, Within an Overall Covering (Three conductor Cable)in Underground Electrical Ducts (One Cable per Electrical Duct) Based on Ambient Earth Temperature of 20 C (68 F) Electrical Duct arrangement in accordance with Figure B.310.15(B)(2)(2), Conductor Temperature 75 C (167 F)" of the National electrical code (NFPA 70).

The conductor size is selected per ampacity criteria applying the temperature adjustment factor and the raceway/cable tray adjustment factor applicable (for conduit, grouping adjustment factor).

Wire size (AWG/kCM)	Ampacity Cond. (75 ℃)	Adj. Factor Conduit/C. Tray	Temp. Adj. Factor at 40.0 ℃	Adjusted Ampacity(Amp)
8	54.00 Amp	0.509	1.0000	27.49
6	71.00 Amp	0.503	1.0000	35.71
4	93.00 Amp	0.493	1.0000	45.85
2	121.00 Amp	0.490	1.0000	59.29
1/0	160.00 Amp	0.453	1.0000	72.48
2/0	183.00 Amp	0.435	1.0000	79.61
3/0	210.00 Amp	0.435	1.0000	91.35
4/0	240.00 Amp	0.431	1.0000	103.44
250	265.00 Amp	0.397	1.0000	105.21
300	265.00 Amp	0.395	1.0000	104.68
350	321.00 Amp	0.395	1.0000	126.80
500	389.00 Amp	0.393	1.0000	152.88

The adjustment factor of the ampacity from the third column of the mentioned table is: 0.393, Calculated with the following break down:

Duct Adjustment Factor	Condition	Value
Harmonic load percentage (Fa)	0 %	1.000
Grouping (> 3 current carrying cond.) (Fag)	Other	1.000
Duct burial depth adj. factor (Fp)	0.75 m	1.000
Shield grounded in 2 points (Fs)		1.000
User defined adj. factor[—](Fu)		1.000
Earth ground temperature adj. factor (Ft)	20 ℃	1.000
Conduit grouping in duct (Fage)	Rows:4 - Columns:6	0.393

$$Factor = Fa \cdot Fag \cdot Fp \cdot Fs \cdot Fu \cdot Ft \cdot Fage$$

The conductor size is selected in accordance with the table previously described, applying the adjustment factors and calculating the adjusted ampacity for 1 conductor per phase, size 500 kCM (152.88 Amp.). And it was verified that the conductor adjusted ampacity from the table is greater than the conductor selection current.

5.1.2 Voltage drop selection

Applying the note of the section 310-15(a)(1) Note 1, which indicates that the ampacity criteria does not take into consideration the circuit voltage drop, it was verified that the conductor size selected meets the requirement of the circuit maximum voltage drop as follows.

In compliance with section 215-2 (a)(1) on the note 3 (for feeders) and/or with the section 210-19 (a)(1) on the note 4 (for branch circuits); a maximum allowable voltage drop of 3.00 % is defined and the following equation was used to calculate the circuit voltage drop expressed as a percentage of the system rated voltage:

$$e\% = \frac{\sqrt{3} \cdot L \cdot F_{Inc} \frac{I_N}{CF} \cdot (R \cdot \cos\theta + X \cdot \sin\theta)}{V \cdot 10}$$

Where:

$e\%$	Voltage drop as a percent of the system voltage[%].
L	Circuit length [meters].
F_{Inc}	Current increase factor [1.000].
I_N	Rated current. [Amp.]
CF	Number of conductors per phase.
R	Resistance [Ω/km].
X	Reactance [Ω/km].
V	System voltage [Volts].
θ	Phase angle between current and voltage.
$\cos\theta$	Power factor.

Applying the resistance and reactance values for a Multiconductor, with a non magnetic raceway /cabletray, from the impedance table: "Table 4A-7-60Hz impedance data for three-phase copper cable circuits, in approximate ohms per 1000 ft at 75C (b) Three conductor cable" del estándar IEEE Std 141, Recommended practice for Electric Power distribution por Industrial Plants (Red Book) para calibres 8 AWG en adelante and from the table 9 "AC Resistance and Reactance for 600 Volt cables, 3 phase, 60 Hz" from National Electrical Code for conductor sizes 14, 12 and 10 AWG

Because the application stores the resistance values using a reference temperature of 90℃, the resistance value is corrected from 90℃ to the termination temperature defined as: 75 ℃ using the following equation:

$$\frac{R_2}{R_1} = \frac{T_2 + T_k}{T_1 + T_k}$$

Where:

T_k	234.5 ℃ for annealed copper with 100 % of conductivity.
R_2	Resistance at ambient temperature [Ω]
R_1	Resistance determined at reference temperature T1 [Ω].
T_2	Ambient temperature at the installation location [℃].
T_1	Temperature used to determine the resistance R1 [℃].

Wire size (AWG/kCM)	Resistance 90℃ (Ω/km)	Resistance 75℃ (Ω/km)	Reactance 60 Hz(Ω/km)	Voltage drop (%)
500	0.0949	0.0905	0.1020	0.6344

It can be concluded that the voltage drop for an arrangement of 1 conductor per phase of 500 kCM nominal size meets with the maximum voltage drop requirement.

5.1.3 Motor starting voltage drop

Considering that the conductor feeds a motor, the voltage drop during the start of it is calculated. Locked-rotor current motor is used for this computation. The power factor during motor start is: 0.31

Wire size (AWG/kCM)	Resistance 90℃ (Ω/km)	Resistance 75℃ (Ω/km)	Reactance 60 Hz(Ω/km)	Voltage drop (%)
500	0.0949	0.0905	0.1020	3.9072

It can be concluded that a starting voltage drop for the arrangement of 1 conductor per phase of 500 kCM nominal size meets with the requirement of the maximum voltage drop during motor start.

5.1.4 Thermal efforts during short-circuit

The minimum area of the conductor to withstand the thermal efforts during a short-circuit condition is calculated using the following equation:

$$(\frac{I}{A})^2 \cdot t = K \cdot \log\left(\frac{T_2 + T}{T_1 + T}\right)$$

Where:

I	Magnitude of the rms short-circuit current [Amperes]
t	Time of the short-circuit duration [seconds] or cycles (cycles/60)
A	Conductor Cross-section [cmills] (1 mm^2 = 1973.52 CMill).
K	Constant depending on the conductor thermal characteristics
	0.0297 for copper conductors
	0.0125 for aluminum conductors.
T_2	Conductor final temperature [℃].
T_1	Conductor initial temperature [℃] (Conductor operation temperature or)
T	234.0 for copper and 228.0 for aluminum [℃]

Therefore, the minimum area of the conductor should be obtained from the previous equation:

$$A = \frac{I}{\sqrt{(\frac{60}{Cycles} \cdot K \cdot \log\left(\frac{T_2+T}{T_1+T}\right))} \cdot 1973.52}$$

$$A = \frac{23000.000}{\sqrt{(\frac{60}{3.00} \cdot 0.0297 \cdot \log\left(\frac{250+234.00}{75+234.00}\right))} \cdot 1973.52}$$

$$A = 34.253(mm^2)$$

This the minimum area required to withstand the short-circuit thermal efforts. Calculating the area required considering the short circuit attenuation by the length, resistance and reactance of the conductor size selected, there is:

Wire Size (AWG/kCM)	Conductor Area (mm^2)	Total Area of 1 CxPh (mm^2)	Isc at eqmnt. (kA)	Minimum required area (mm^2)
500	253.00	253.00	10.1671	15.14

It is therefore concluded that the selection of 1 conductor per phase, size 500 kCM meets the requirements of thermal efforts imposed by short-circuit currents.

6 Summary of the conductor final size

Following is presented the selected conductor size for the circuit 01-MOT-05-F describing the different criteria compliance:

Selection Criteria	Conductor Size	Conductor(s) per phase
Conductor ampacity	500 kCM	1
Voltage drop	500 kCM	1
Starting voltage drop	500 kCM	1
Thermal efforts during SC.	500 kCM	1
Final Selection	**500 kCM**	**1**

Conduit diameter suggested (mm/plg): 103.0/4.00 filled at Excedido of the maximum electrical area allowable.

7 Conclusions

In accordance with the calculation procedure the Copper conductor, size 500 kCM meets the allowable ampacity criteria , voltage drop under normal operation, maximum voltage drop during motor starting and thermal efforts during short-circuit conditions.

Generic description for the conductor finally selected for this circuit is:

Multiconductor: CU-3*500-600-XHHW_2-90-100-TC-PWR-NOS-BLK-PVC
Copper Power Conductor, 3*500 (AWG/kCM) wire size, Multiconductor, XHHW_2 insultation type, 100 % Insulation level, 90 °C Operation temperature, 600 Volts rated voltage, TC type, No Shield, Black color, PVC overall jacket, Sizer Electric, Catalog number: No Information, Product URL: https://sizerelectric.com/especs/info.php?file=f4