# Welcome

# CABLE SIZING

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# CABLE SIZING - OVERVIEW

CABLE SIZING IS A VERY IMPORTANT STEP IN ELECTRICAL ENGINEERING. SINCE ALL ELECTRICAL EQUIPMENTS WOULD NOT FUNCTION WITHOUT A CONDUCTOR RUNNING BETWEEN THE SOURCE AND THE LOAD, CABLES MAKE UP A SIGNIFICANT PORTION IN ELECTRICAL ENGINEERING.

IN TYPICAL EPC PROJECT, CABLE QTY (BASED ON PERCENTAGE OF TOTAL BOQ ITEMS) MAKE UP ABOUT **20-40%+** OF TOTAL ELECTRICAL COST.

# CABLE SIZING - OVERVIEW

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ALTHOUGH THE AMOUNT OF CABLES DEPENDS ON THE SCOPE AND SIZE OF THE PLANT, CABLE SIZING STILL REMAINS A CRUCIAL ASPECT IN ELECTRICAL ENGINEERING.

NOT ONLY DOES IT GOVERN THE **COST** OF ELECTRICAL SYSTEM, IT ALSO GOVERNS THE **SAFETY** OF THE ENTIRE ELECTRICAL SYSTEM.

# CABLE SIZING - OVERVIEW

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IF A CABLE IS NOT SIZE PROPERLY, THE FOLLOWING THINGS COULD OCCUR:

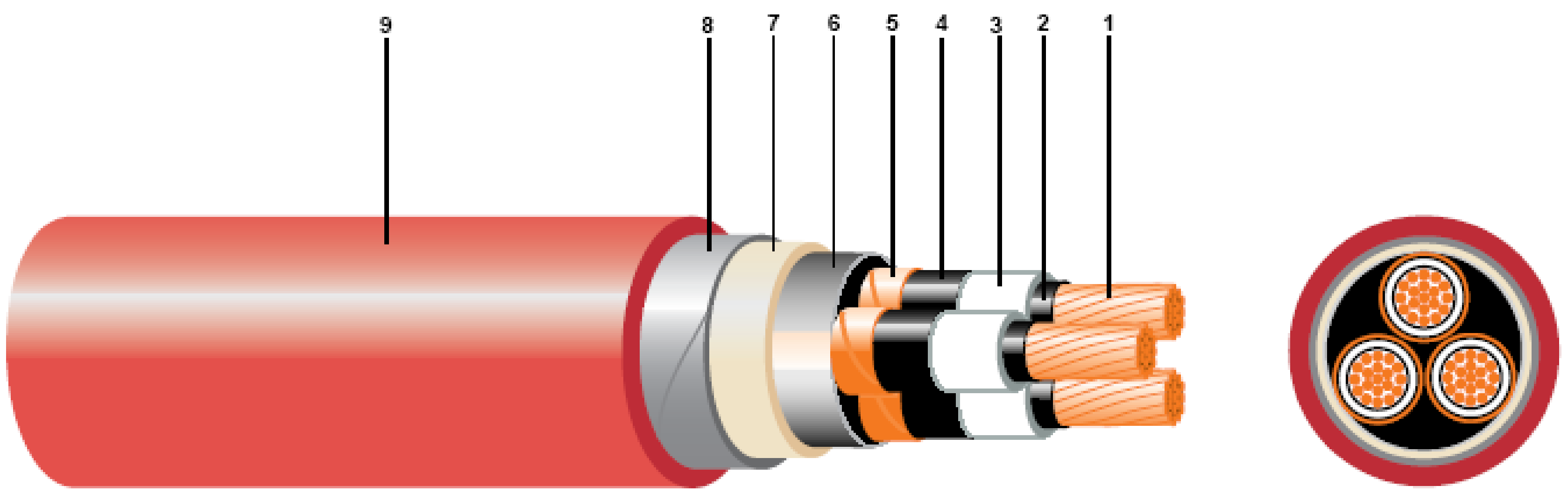
- THE EQUIPMENT IS NOT POWERED PROPERLY (INSUFFICIENT VOLTAGE)
- THE CABLE COULD OVERHEAT, CAUSING INSULATION TO FAIL/PARTIAL DISCHARGE AND FIRES TO OCCUR.
- AS A RESULT OF THE ABOVE, A WHOLE SECTION OF CABLE TRAY / TRENCH COULD BURN-OUT CAUSING PLANT FAILURE.

# CABLE SIZING - CONSTRUCTION

BEFORE WE DELVE INTO THE PROCESS OF CABLE SIZING, LET'S TAKE A LOOK AT A TYPICAL CABLE CONSTRUCTION:

CU/XLPE/CTS/PVC/DTA/PVC

1. Conductor
2. Conductor Screen
3. Insulation
4. Insulation Screen (non-metallic part)
5. Insulation Screen (metallic part)
6. Non-hygroscopic fillers and separator tape
7. Bedding
8. Armour
9. Outer Sheath



# CABLE SIZING – CONSTRUCTION

## CABLE CONDUCTOR

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THE CABLE CONDUCTOR CAN BE:

-ALUMINUM

-COPPER

SELECTION OF THESE ARE DEPENDENT ON CLIENT, WITH A NOTABLE IN PRICE FOR ALUMINUM, BUT WITH LESS AMPACITY RATING COMPARED TO COPPER.

As per IEC 60502

# CABLE SIZING – CONSTRUCTION
## CONDUCTOR SCREEN

THE CONDUCTOR SCREEN CAN BE:

-NON-METALLIC

-CONSISTS OF EXTRUDED SEMI-CONDUCTING COMPOUND, WHICH MAY BE APPLIED ON THE TOP OF THE SEMI CONDUCTING TAPE.

IT IS TYPICALLY A NON-METALLIC SEMI-CONDUCTING SCREEN BEFORE INSULATION, PROVIDED FOR ELECTRICAL SHIELDING IF SPECIFIED BY THE CLIENT.

As per IEC 60502

# CABLE SIZING – CONSTRUCTION
## INSULATION

THERMOPLASTIC:
-PVC
THERMOSETTING:
-XLPE
-EPR
-HEPR

TYPICAL INSULATION IS EITHER PVC OR XLPE.

| Insulating Compound | Max Conductor Temperature °C | |
|---|---|---|
| | Normal | S.C |
| PVC (≤300mm$^2$) | 70 | 160 |
| (>300mm$^2$) | 70 | 140 |
| XLPE | 90 | 250 |
| EPR & HEPR | 90 | 250 |

As per IEC 60502

# CABLE SIZING – CONSTRUCTION
## INSULATION SCREEN

THE CONDUCTOR SCREEN IS:

-NON-METALLIC, SEMI CONDUCTING IN COMBINATION WITH A METALLIC LAYER.

-SEMI-CONDUCTING TAPE

IT IS TYPICALLY USED IN **MV CABLES** AT THE REQUEST OF CLIENT, WHERE COPPER TAPE SCREEN (CTS) IS USED FOR EARTH FAULT CURRENT PATH.

As per IEC 60502

# CABLE SIZING – CONSTRUCTION
## FILLER

INTERSTICES BETWEEN THE CORES ARE FILLED WITH NON-HYGROSCOPIC FILLER (WHICH IS USUALLY A SOFT POLYMER, LIKE PVC), ALSO ON THE OUTSIDE OF THE INSULATED CONDUCTORS.

THIS KEEPS THE CABLE CORES IN-PLACE AND RETAINS THE CIRCULAR SHAPE OF THE CABLE.

As per IEC 60502

# CABLE SIZING – CONSTRUCTION
## BEDDING

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# BEDDING IS USUALLY EXTRUDED-PVC, WHICH SERVES AS A PROTECTION OF THE LAID-UP CORES, AND PROVIDES BEDDING FOR CABLE ARMOUR.

As per IEC 60502

# CABLE SIZING – CONSTRUCTION
## ARMOUR

CABLE ARMOURS CAN BE:

- GALVANIZED STEEL FLAT WIRE OR ROUND WIRE
- ALUMINIUM OR ALUMINIUM ALLOY FOR SINGLE-CORE CABLES
- DOUBLE TAPE STEEL, GALVANIZED STEEL, ALUMINIUM OR ALUMINIUM ALLOY

ARMOUR IS PROVIDED FOR MECHANICAL PROTECTION OF CABLE. IT IS ALSO PROVIDED AS REQUESTED BY CLIENT, AND USUALLY FOR UNDERGROUND/TRENCH LAYED CABLES.

As per IEC 60502

# CABLE SIZING – CONSTRUCTION
## OUTER SHEATH

- NORMALLY BLACK (OTHERWISE RED OR ORANGE)

  LV CABLES ARE USUALLY BLACK, WHILE MV CABLES ARE RED

- PVC OR POLYETHYLENE (THERMOPLASTIC)
- CHEMICAL ADDITIVES FOR CABLE PROTECTION

As per IEC 60502

# CABLE SIZING – CONSTRUCTION
## VOLTAGE SELECTION

VOLTAGE OF CABLES IS DESIGNATED AS:

**$U_o$/U (UM)**

WHERE:

- **$U_o$** – RATED POWER FREQUENCY VOLTAGE BETWEEN CONDUCTOR & EARTH OR METALLIC SCREEN
- **U** – RATED POWER FREQUENCY VOLTAGE BETWEEN CONDUCTORS
- **UM** – MAXIMUM VALUE OF THE “HIGHEST SYSTEM VOLTAGE” FOR WHICH EQUIPMENT MAY BE USED

As per IEC 60502

# CABLE SIZING – CONSTRUCTION

## VOLTAGE SELECTION

SOME EXAMPLES/COMMON IEC VOLTAGE DESIGNATION OF CABLES ARE (NOTE, UNITS IN THIS NOTATION ARE IN **KV**):

- LV CABLES : .6/1(1.2) OR TYPICALLY **.6/1**
- MV CABLES :

  3.6/6(7.2), 6/10(12), 8.7/15(17.3), 12/20 (24)

As per IEC 60502

# CABLE SIZING - CONSTRUCTION

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ANY QUESTIONS?

# CABLE SIZING – CALCULATION

SIZING FOR CABLES IS DONE IN 3 AREAS/CRITERIAS:

1. FAULT LEVEL WITHSTAND CAPABILITY (MINIMUM SIZE OF CABLE)
2. CONTINUOUS CURRENT CARRYING CAPACITY (DERATING DUE TO ENVIRONMENT)
3. VOLTAGE DROP ON CABLES (TERMINAL VOLTAGE AT LOAD, DURING RUNNING & START-UP)

# CABLE SIZING – CALCULATION

## FAULT LEVEL WITHSTAND

CALCULATION FOR MINIMUM SIZE BASED ON SHORT CIRCUIT / FAULT LEVEL WITHSTAND IS BASED ON THE FOLLOWING FORMULA:

$$S_{min} = I_{cc} \frac{\sqrt{t}}{k}$$

$S_{min} = minimum\ required\ cross-section\ (mm^2)$

$I_{cc} = maximum\ short-circuit\ level\ (kA)$

$t = short\ circuit\ duration\ (\text{seconds})$

$k = constant; XLPE\ Insulated\ copper\ cable = 0.1431$

# CABLE SIZING – CALCULATION

## FAULT LEVEL WITHSTAND

THE CONSTANT K IS DIFFERENT FOR COPPER & ALUMINUM CONDUCTORS, WHICH IS ALSO DIFFERENT BASED ON THE TYPE OF INSULATION (XLPE, OR PVC).

AS NOTED, K FOR XLPE INSULATED CABLES IS COMMONLY 143.1 (FOR SC I IN AMPERES) OR .1431 (FOR SC I IN KA).

THIS K IS DERIVED FROM THE FOLLOWING FORMULAS (BASED ON IEC 60364-5-54):

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

(COPPER CONDUCTORS)

$$k = 148\sqrt{\ln\left(1 + \frac{\theta_f - \theta i}{228 + \theta_i}\right)}$$

(ALUMINUM CONDUCTORS)

# CABLE SIZING – CALCULATION

## FAULT LEVEL WITHSTAND

IN THE FORMULA BEFORE:

$$\theta_i = initial\ temperature\ of\ conductor\ (\deg C)$$

$$\theta_f = final\ temperature\ of\ conductor\ (\deg C).$$

**INITIAL TEMPERATURE** IS TYPICALLY CHOSEN FROM MAXIMUM OPERATING TEMPERATURE OF THE CABLE.

WHILE THE **FINAL TEMPERATURE** IS TYPICALLY CHOSEN FROM THE LIMITING TEMPERATURE OF THE INSULATION.

FOR THESE TEMPERATURES, ROUGHLY THE FOLLOWING TABLE IS FOLLOWED:

| Material | Max Operating Temperature ºC | Limiting Temperature ºC |
|---|---|---|
| PVC | 75 | 160 |
| EPR | 90 | 250 |
| XLPE | 90 | 250 |

# CABLE SIZING – CALCULATION

## FAULT LEVEL WITHSTAND

$$S_{min} = I_{cc}\frac{\sqrt{t}}{k}$$

$$I_{cc} = maximum\,short - circuit\;level\;(kA)$$

**MAXIMUM SHORT CIRCUIT IS BASED ON THE KA RATING OF THE CONNECTED SWITCHGEAR/MCC BUS.**

# CABLE SIZING – CALCULATION

## FAULT LEVEL WITHSTAND

$$S_{min} = I_{cc}\,\frac{\sqrt{t}}{k}$$

$$t = short\ circuit\ duration\ (\text{seconds})$$

FOR THE SHORT CIRCUIT DURATION, IN THEORY THIS WOULD BE BASED ON THE SC WITHSTAND TIME OF THE SWITCHGEAR/MCC BUS AS WELL. ALTHOUGH IT IS SAFE TO SIZE IT THIS WAY, THIS WILL CAUSE THE MINIMUM CABLE SIZE TO BE OVERSIZED UN-REALISTICALLY.

THEREFORE, T HERE IS COMMONLY CONSIDERED TO BE THE TRIPPING TIME OF THE BREAKER/FUSE CONNECTED TO THE CABLE.

FOR MV (VCB/ACB), THIS IS ROUGHLY .25 SECONDS.
FOR LV MCB/FUSE, THIS IS ROUGHLY .1 MS OR .001 SECONDS (SOMETIMES LESS).

TO GET AN MORE REALISTIC FIGURE, WE WOULD HAVE TO CONSULT WITH THE VENDOR BREAKER CATALOGUE FOR THE ACTUAL OR STANDARD TRIPPING TIME OF THE PROTECTIVE DEVICE.

# CABLE SIZING – CALCULATION

## CONTINUOUS CURRENT CARRYING CAPACITY

CONSIDERATION FOR CONTINUOUS CURRENT CARRYING CAPACITY IS MAINLY BASED ON VENDOR CATALOGUES, LISTING VARIOUS AMPERE RATINGS, FOR VARIOUS SIZES OF CABLES.

THE AMPERE RATING LISTED IN A VENDOR CATALOGUE CONSIDERS CERTAIN ENVIRONMENT AND INSTALLATION CONDITIONS.

# CABLE SIZING – CALCULATION

## CONTINUOUS CURRENT CARRYING CAPACITY

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THOSE CONDITIONS THAT AFFECT THE AMPACITY OF CABLES ARE:

-THERMAL RESISTIVITY OF SOIL (IF BURIED)

-DEPTH OF LAYING (IF BURIED)

-AMBIENT TEMPERATURE (ABOVE/UNDER GROUND)

-LAYING OF CONDUCTORS

THE CONDITIONS STATED BY VENDOR FOR THOSE CONDITIONS NEED TO BE NOTED, BECAUSE THESE WILL AFFECT THE **DERATING FACTORS**.

# CABLE SIZING – CALCULATION

## CURRENT DERATING – THERMAL RESISTIVITY

## TYPICAL TABLE OF CORRECTION FACTORS FOR THERMAL RESISTIVITY:

Rating factor relating to themal ground resistivity

| Thermal Resistivity of soil K.m / W | 1 | 1.5 | 2 | 2.5 | 3 |
|---|---|---|---|---|---|
| Rating factors | 1.18 | 1.1 | 1.05 | 1.00 | 0.96 |

IN THIS CASE, VENDOR CATALOGUE PROVIDES DATA WITH **2.2** K.M/W THERMAL RESISTIVITY.

IF SITE CONDITIONS SAYS THERMAL RESISTIVITY OF SOIL IS 1.5 K.M/W, THEN THE CORRECTION FACTOR FOR AMPACITY SHALL BE **1.1**

# CABLE SIZING – CALCULATION

## CURRENT DERATING – DEPTH OF LAYING

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**FOR DEPTH OF LAYING, TYPICAL TABLE OF CORRECTION FACTORS IS:**

Correction factors for depths of laying for direct buried cables

| Depth of laying m | Single-core cables – Nominal conductor size mm² ≤ 185 mm² | Single-core cables – Nominal conductor size mm² ≥ 185 mm² | Three-core cables |
|---|---|---|---|
| 0.5 | 1.04 | 1.06 | 1.04 |
| 0.6 | 1.02 | 1.04 | 1.03 |
| 0.8 | 1 | 1 | 1 |
| 1 | 0.98 | 0.97 | 0.98 |
| 1.25 | 0.96 | 0.95 | 0.96 |
| 1.5 | 0.95 | 0.93 | 0.95 |
| 1.75 | 0.94 | 0.91 | 0.94 |
| 2 | 0.93 | 0.90 | 0.93 |
| 2.5 | 0.91 | 0.88 | 0.91 |
| 3 | 0.90 | 0.86 | 0.90 |

# CABLE SIZING – CALCULATION

## CURRENT DERATING – AMBIENT TEMPERATURE

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AMBIENT TEMPERATURE IS CONSIDERED FOR BOTH UNDERGROUND AND ABOVE GROUND CABLES.

TYPICAL CORRECTION FACTOR FOR AMBIENT TEMPERATURE ARE:

**Correction factors for ambient Air temperatures**

| Max.conductor temperature °C | Ambient air temperature °C | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 |
| 90 | 1.08 | 1.04 | 1 | 0.96 | 0.91 | 0.87 | 0.82 | 0.76 | 0.71 |

**Correction factors for ambient Ground temperatures**

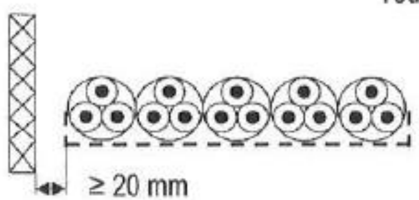
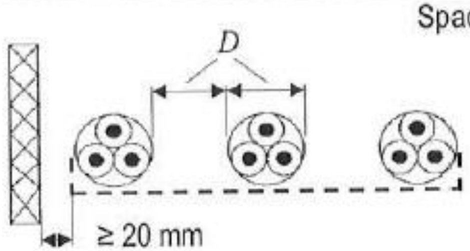
| Max.conductor temperature °C | Ambient Ground temperature °C | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| 90 | 1.07 | 1.04 | 1 | 0.96 | 0.93 | 0.89 | 0.85 | 0.80 | 0.76 |

# CABLE SIZING – CALCULATION

## CURRENT DERATING – CABLE GROUPING



CABLE GROUPING IS BASED ON PLANNED/ACTUAL LAYING CONDITIONS. PROXIMITY AND QUANTITY OF CABLES AFFECT THE RATING OF THE CABLES, AS INDICATED IN A TYPICAL GROUPING TABLE AS FOLLOWS:

| Method of installation | Number of trays | Number of cables | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 6 | 9 |
| Touching   | 1 | 1.00 | 0.88 | 0.82 | 0.79 | 0.76 | 0.73 |
| | 2 | 1.00 | 0.87 | 0.80 | 0.77 | 0.73 | 0.68 |
| | 3 | 1.00 | 0.86 | 0.79 | 0.76 | 0.71 | 0.66 |
| Spaced   | 1 | 1.00 | 1.00 | 0.98 | 0.95 | 0.91 | - |
| | 2 | 1.00 | 0.99 | 0.96 | 0.92 | 0.87 | - |
| | 3 | 1.00 | 0.98 | 0.95 | 0.91 | 0.85 | - |

# CABLE SIZING – CALCULATION

## CURRENT DERATING – CABLE GROUPING

NOTE THAT CABLE GROUPING FACTORS ARE USUALLY COMMON EITHER FOR ABOVE-GROUND INSTALLATION / UNDERGROUND INSTALLATION. THIS FACTOR IS MORE CLOSELY RELATED TO PROXIMITY OF CABLES THAN LOCATION/TEMPERATURE.

FEW THINGS TO CONSIDER AS WELL:

- MV CABLES TYPICALLY HAS SPACE OF 2D CENTER-TO-CENTER.
- LV CABLES TYPICALLY ARE ALWAYS TOUCHING
- WORST CASE TOUCHING CASE IS TYPICALLY TAKEN FOR STANDARD OF CABLE SIZING.

# CABLE SIZING – CALCULATION

## TOTAL DERATING FACTOR

SO AFTER DETERMINING THE CORRECTION FACTORS BASED ON THE ABOVE POINTS, WE FIND **TOTAL DERATING FACTOR**, AS FOLLOWS:

$$DF\ (ABOVEGROUND) = C_T \times C_G$$

$$DF\ (UNDERGROUND) = C_T \times C_D \times C_G \times C_S$$

WHERE:

$C_T = Correction\ factor\ for\ temperature$

$C_D = Correction\ factor\ for\ laying\ depth$

$C_G = Correction\ factor\ for\ grouping$

$C_S = Correction\ factor\ for\ thermal\ resistivity$

# CABLE SIZING – CALCULATION

## TOTAL DERATING FACTOR

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HENCE THE AMPERE RATING OF THE CATALOGUE SHALL BE MULTIPLIED BY THIS DERATING FACTOR TO OBTAIN **THE DERATED RATING** OF THE CABLE, WHICH IS USED FOR SIZING THE CABLE.

*FOR EXAMPLE,* FOR 3C X 50 MM2 CABLE, IF DF IS **.6**, AND THE RATING AS PER CATALOGUE IS **192 A**, THEN THE ACTUAL MAXIMUM RATING TO CONSIDER IS:

**192 A X .6 = 115 A**

# CABLE SIZING – CALCULATION

## VOLTAGE DROP

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CABLE SIZING BASED ON VOLTAGE DROP DEALS WITH THE RESISTANCE & REACTANCE OF THE CABLE (DATA GIVEN BY VENDOR), AND ALSO THE DISTANCE OF THE CABLE.

IN THEORY, THE LONGER THE DISTANCE, THE LARGER THE VOLTAGE DROP. AND FOR LOW VOLTAGE, THIS BECOMES INCREASINGLY IMPORTANT, WHICH IS WHY LOW VOLTAGE CABLES OFTEN END UP WITH MULTIPLE RUNS OF CABLES.

# CABLE SIZING – CALCULATION
## VOLTAGE DROP

THE CALCULATION FOR VOLTAGE DROP IS AS FOLLOWS:

$$V_d = \frac{\sqrt{3} \times I \times (R\cos\theta + X\sin\theta) \times L}{V_s \times N}$$

## WHERE:

$V_d = Voltage\ Drop\ (V)$

$R = Cable\ Resistance\ at\ Max\ Conductor\ Temperature\ (90°\mathrm{C})(\Omega/\mathrm{km})$

$X = Cable\ Reactance\ at\ 50Hz\ (\Omega/\mathrm{km})$

$\cos\theta = Power\ Factor$

$L = Cable\ Length$

$V_s = System\ Voltage$

$N = Number\ of\ 3 - Phase\ Runs$

# CABLE SIZING

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ANY QUESTIONS?

# THANK YOU!!