طرح نگهداشت و افزایش تولید ۲۷ مخزن

CALCULATION NOTE FOR CABLE SIZING

نگهداشت و افزایش تولید میدان نفتی بینک

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REVISION RECORD SHEET

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1.0 INTRODUCTION

Binak oilfield in Bushehr province is a part of the southern oilfields of Iran, is located 20 km northwest of Genaveh city.

With the aim of increasing production of oil from Binak oilfield, an EPC/EPD Project has been defined by NIOC/NISOC and awarded to Petro Iran Development Company (PEDCO). Also PEDCO (as General Contractor) has assigned the EPC-packages of the Project to "Hirgan Energy - Design and Inspection" JV.

As a part of the Project, a New Gas Compressor Station (adjacent to existing Binak GCS) shall be constructed to gather of 15 MMSCFD (approx.) associated gases and compress & transfer them to Siahmakan GIS.

GENERAL DEFINITION

The following terms shall be used in this document.

CLIENT:	National Iranian South Oilfields CLIENT (NISOC)
PROJECT:	Binak Oilfield Development – Surface Fcilities; New Gas Compressor Station
EPD/EPC CONTRACTOR (GC):	Petro Iran Development Company (PEDCO)
EPC CONTRACTOR:	Joint Venture of : Hirgan Energy – Design & Inspection (D&I) Companies
VENDOR:	The firm or person who will fabricate the equipment or material.
EXECUTOR:	Executor is the party which carries out all or part of construction and/or commissioning for the project.
THIRD PARTY INSPECTOR (TPI):	The firm appointed by EPD/EPC CONTRACTOR (GC) and approved by CLIENT (in writing) for the inspection of goods.
SHALL:	Is used where a provision is mandatory.
SHOULD:	Is used where a provision is advisory only.
WILL:	Is normally used in connection with the action by CLIENT rather than by an EPC/EPD CONTRACTOR, supplier or VENDOR.
MAY:	Is used where a provision is completely discretionary.

2.0 SCOPE

This document describes the electrical cables cross-section calculation and selection. In this document, a general methodology for cable sizing is presented.

3.0 NORMATIVE REFERENCES

3.1 Local Codes & Standards

- IPS-E-EL-100 (1) Engineering Standard for Electrical System
- IPS-M-EL-271(2) Material and equipment standard for LV cables & wires
- IPS-M-EL-272 (2) Material & equipment standard for medium & high voltage power cable
- IPS-C-EL-115 Construction standard for electrical installation

3.2 International Codes & Standard

- IEC 60364-5-52 Low voltage electrical installations, selection and erection of electrical equipment-wiring system
- IEC 60364-5-54 Electrical installations of buildings, selection and erection of electrical equipment-earthing arrangements, protective conductors and protective bonding conductors
- IEC 60364-4-43 Low-voltage electrical installations - Part 4-43: Protection for safety – Protection against overcurrent
- D04 IEC 60502-1 Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) Part 1: Cables for rated voltages of 1 kV (Um = 1,2 kV) and 3 kV (Um = 3,6 kV)
- IEC 60502-2 Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) Part 1: Cables for rated voltages of 1 kV (Um = 1,2 kV) and 3 kV (Um = 3,6 kV)
- IEC 60502-2 Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV)- Part 2: Cables for rated voltages from 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)
- IEC 60228 Conductors of insulated cables
- IEC 60287 Electric cables - Calculation of the current rating
- IEC 60332 Tests on electric and optical fibre cables under fire conditions

3.3 The Project Documents

- BK-GCS-PEDCO-120-EL-LI-0001 Electrical Load List
- BK-GNRAL-PEDCO-000-EL-DC-0001 Electrical System Design Criteria
- BK-GNRAL-PEDCO-000-EL-SP-0014 Specification for Power & Control Cables

3.4 Environmental Data

Refer to "Process Basis of Design; Doc. No. BK-GNRAL-PEDCO-000-PR-DB-0001"

3.5 Order of Precedence

In case of conflict between requirements specified herein & the requirements of any other referenced document, the most approved stringent requirements of below listed items shall be considered based on the approval given by the owner's representative:

- Purchase order
- Material Requisition
- MTO & Data Sheet
- This Specification
- Drawing & Other Specification
- Reference Project Specification
- Iranian Petroleum Standard (IPS)
- Reference international Code & Standards

When the term “Authorized”, Authorization”, “Approval”, or “Approved” are used in this specification, it shall mean authorization or Approval from OWNER.

In case of any conflict between the project documents, the most stringent one shall be considered.

4.0 CABLE CONSTRUCTION

According to cables specification, the cables construction is as follows

- Conductor: Copper stranded conductors
- Insulation Material: XLPE
- Shield: Extruded semi-conducting shield + plain annealed copper screen per core for MV type
- Armour: Most of cables are steel wire armour for multicore cables and Aluminium wire armour for single cores.
- Cover: Lead sheath

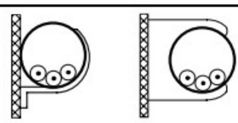
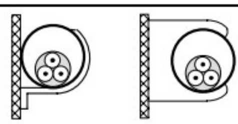
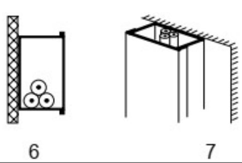
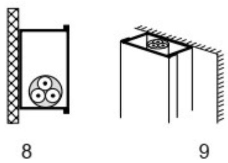
- Inner sheath: PVC
- Outer sheath: PVC
- Maximum Conductor Temp.: 90°C

5.0 CABLE INSTALLATION

Generally power and control cables in area shall be installed in cable trench. Distance between MV and LV cables in rows and columns will be determined according to the cabling system installation standards based on IPS-C-EL-115.

Outdoor cables will be directly buried in ground. In this case installation method "D" of IEC is applicable (according to Table A.52.3 of IEC 60364-5-52).

Table A.52.3 – Examples of methods of installation providing instructions for obtaining current-carrying capacity

Item No.	**Methods of installation**	**Description**	**Reference method of installation to be used to obtain current-carrying capacity** (see Annex B)
1		Insulated conductors or single-core cables in conduit in a thermally insulated wall[a, c]	A1
2		Multi-core cables in conduit in a thermally insulated wall[a, c]	A2
3		Multi-core cable direct in a thermally insulated wall[a, c]	A1
4		Insulated conductors or single-core cables in conduit on a wooden or masonry wall or spaced less than 0,3 × conduit diameter from it[c]	B1
5		Multi-core cable in conduit on a wooden or masonry wall or spaced less than 0,3 × conduit diameter from it [c]	B2
6 7		Insulated conductors or single-core cables in cable trunking (includes multi-compartment trunking) on a wooden or masonry wall – run horizontally[b] – run vertically[b, c]	B1
8 9		Multi-core cable in cable trunking (includes multi-compartment trunking) on a wooden or masonry wall – run horizontally[b] – run vertically[b, c]	Under consideration[d] Method B2 may be used

NOTE 1 The illustrations are not intended to depict actual product or installation practices but are indicative of the method described.

NOTE 2 All footnotes can be found on the last page of Table A.52.3.

Table A.52.3 (*continued*)

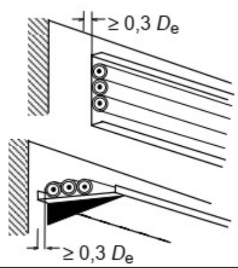
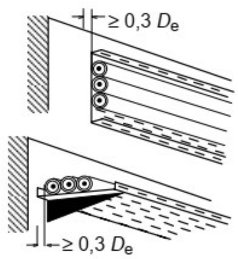
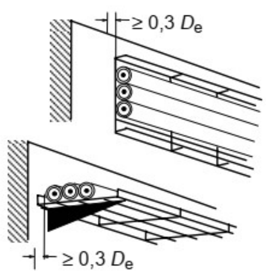
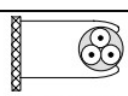
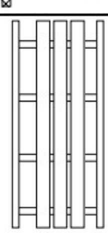
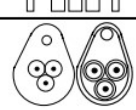
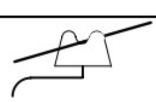
Item No.	Methods of installation	Description	Reference method of installation to be used to obtain current-carrying capacity (see Annex B)
30		Single-core or multi-core cables: On unperforated tray run horizontally or vertically[c, h]	C with item 2 of Table B.52.17
31		Single-core or multi-core cables: On perforated tray run horizontally or vertically[c, h] NOTE Refer to B.52.6.2 for description	E or F
32		Single-core or multi-core cables: On brackets or on a wire mesh tray run horizontally or vertically[c, h]	E or F
33		Single-core or multi-core cables: Spaced more than 0,3 times cable diameter from a wall	E or F or method G[g]
34		Single-core or multi-core cables: On ladder[c]	E or F
35		Single-core or multi-core cable suspended from or incorporating a support wire or harness	E or F
36		Bare or insulated conductors on insulators	G

Table A.52.3 (*continued*)

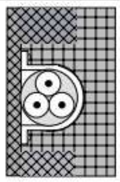
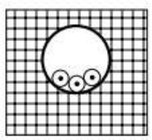
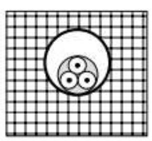
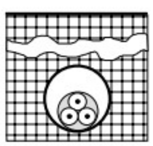
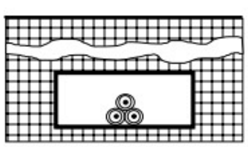
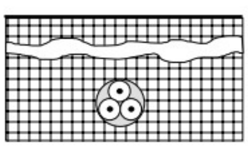
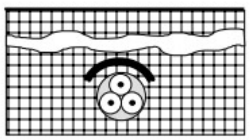
Item No.	Methods of installation	Description	Reference method of installation to be used to obtain current-carrying capacity (see Annex B)
58		Single-core or multi-core cable direct in masonry having a thermal resistivity not greater than 2 K·m/W With added mechanical protection[o, p]	C
59		Insulated conductors or single-core cables in conduit in masonry[p]	B1
60		Multi-core cables in conduit in masonry[p]	B2
70		Multi-core cable in conduit or in cable ducting in the ground	D1
71		Single-core cable in conduit or in cable ducting in the ground	D1
72		Sheathed single-core or multi-core cables direct in the ground – without added mechanical protection[q]	D2

Table A.52.3 (*continued*)

Item No.	Methods of installation	Description	Reference method of installation to be used to obtain current-carrying capacity (see Annex B)
73		Sheathed single-core or multi-core cables direct in the ground – with added mechanical protection[q]	D2

[a] The inner skin of the wall has a thermal conductance of not less than 10 W/m^2·K.

[b] Values given for installation methods B1 and B2 in Annex B are for a single circuit. Where there is more than one circuit in the trunking the group reduction factor given in Table B.52-17 is applicable, irrespective of the presence of an internal barrier or partition.

[c] Care shall be taken where the cable runs vertically and ventilation is restricted. The ambient temperature at the top of the vertical section can be increased considerably. The matter is under consideration.

[d] Values for reference method B2 may be used.

[e] The thermal resistivity of the enclosure is assumed to be poor because of the material of construction and possible air spaces. Where the construction is thermally equivalent to methods of installation 6 or 7, reference method B1 may be used.

[f] The thermal resistivity of the enclosure is assumed to be poor because of the material of construction and possible air spaces. Where the construction is thermally equivalent to methods of installation 6, 7, 8, or 9, reference methods B1 or B2 may be used.

[g] The factors in Table B.52.17 may also be used.

[h] D_e is the external diameter of a multi-core cable:
- 2,2 × the cable diameter when three single core cables are bound in trefoil, or
- 3 × the cable diameter when three single core cables are laid in flat formation.

[i] V is the smaller dimension or diameter of a masonry duct or void, or the vertical depth of a rectangular duct, floor or ceiling void or channel. The depth of the channel is more important than the width.

[j] D_e is the external diameter of conduit or vertical depth of cable ducting.

[l] D_e is the external diameter of the conduit.

[m] For multi-core cable installed in method 55, use current-carrying capacity for reference method B2.

[n] It is recommended that these methods of installation are used only in areas where access is restricted to authorized persons so that the reduction in current-carrying capacity and the fire hazard due to the accumulation of debris can be prevented.

[o] For cables having conductors not greater than 16 mm^2, the current-carrying capacity may be higher.

[p] Thermal resistivity of masonry is not greater than 2 K·m/W, the term “masonry” is taken to include brickwork, concrete, plaster and the like (other than thermally insulating materials).

[q] The inclusion of directly buried cables in this item is satisfactory when the soil thermal resistivity is of the order of 2,5 K·m/W. For lower soil resistivities, the current-carrying capacity for directly buried cables is appreciably higher than for cables in ducts.

Items 72/73 of this Table corresponds to direct burial installation of cables and item 70 corresponds to installation of cables in sleeves in the duct banks. Underground installation of cables inside buildings shall be in cable ladders inside concrete trenches or false floors. In this case installation method E or F will be applicable.

6.0 CABLE SIZING CRITERIA

The cables will be sized with the following design criteria:

- Current rating
- Voltage drop
- Short circuit capacity
- IPS standard

All HV/MV/LV distribution feeders, DC and UPS service cables will be individually sized. Cable current ratings and impedances are taken from typical standard data, as referred in section 12. They are applicable for a specific ground thermal resistance of 2.5 K.m/W, for a soil temperature of 20°C and for laying at a depth of 0.6m to 1m. These ratings are based on Iranian manufactures, with the application of correction factors for different ground temperature and cables laying and grouping. The tables shall be superseded by actual ratings of the cables for this project after vendor data received.

Cable sizes will be rationalized in order to reduce the number of different cable types and sizes on the project.

7.0 CABLE SIZING PROCEDURE

In this section sizing procedure for each criterion mentioned will be studied. Examples are only for illustration of calculation method and current carrying capacities and impedance data that are given in tables can be used in the absence of manufacturers' data.

7.1 Current Carrying Capacity

- Underground Installation

Current carrying-capacity shall be greater than the full load current divided by de-rating factor "f".

Where:

f = f1 x f2 x f3 x f4 (1)

In which

f: Overall de-rating factor

f1: De-rating factor for different ambient ground temperature other than 35°C

f2: De-rating factor for different soil thermal resistivity other than 2.5 K.m/W

f3: De-rating factor for different typical installation (Grouping factor)

f4: De-rating factor for depths of laying other than 1m for direct buried cables

Note: Reference tables for coefficients f1 to f4 are referred in section 11 based on related standards for LV and MV cables, separately.

- Aboveground Installation

Current carrying-capacity shall be greater than the full load current divided by de-rating factor “f”.

Where:

f = f1 x f2 (2)

In which

f : Overall de-rating factor

f1: De-rating factor for different ambient air temperature other than 52°C

f2: De-rating factor for different typical installation (Grouping factor)

Note: Reference tables for coefficients f1 and f2 are referred in section 11 based on related standards for LV and MV cables, separately.

7.2 Voltage Drop

Voltage drop will be calculated by following equations

$$\Delta u = \frac{\sqrt{3}\times LI\times(RCos\emptyset+XSin\emptyset)}{U_N}\times 100$$ (3) (For 3 Phase System)

$$\Delta u = \frac{2\times LI\times(RCos\emptyset+XSin\emptyset)}{U_N}\times 100$$ (4) (For 1 Phase System)

$$\Delta u = \frac{2\times LIR}{U_N}\times 100$$ (5) (For direct current System)

Where

Δu : Voltage Drop [%]

I : Rated Current [A]

L : Length of Cable [km]

R : Unit Length Resistance [Ω/km]

X : Unit Length Reactance [Ω/km]

U_N : Nominal Voltage [V]

$Cos\emptyset$: Power Factor

For motor starting conditions voltage drop calculation, power factor will be considered as IPS-E-EL-100 recommendation where no exact manufacturer data's present.

The electrical power system shall be designed to limit voltage drop (based on nominal voltage) in the feeder cables to the following values:

Feeders to transformers: 1%

Feeders to switchboards: 1%

Power source to panel board: 2%

MV Motor branch circuits: 3.25% at full load

LV Motor branch circuits: 5% at full load

Lighting circuits:

- 3% between lighting panel board and the most distant fixture
- 2% between 400V switchgear and lighting panel board

The maximum voltage drop in the motor feeder cable during motor starting shall be limited to 15% of the nominal voltage.

7.3 Short Circuit Capacity

Based on IEC 60724, the following formula will be used to calculate the minimum required cross section of cores, to restrict temperature rise below 250°C for XLPE and 160°C for PVC.

$$S_{min} = \frac{I_{sc} \times \sqrt{T_P}}{K_{sc}} \qquad (6)$$

Where:

S_{min} : Minimum Required Cross Section of Cores

I_{sc} : Short Circuit Current

T_P : is the duration in seconds and shall consist of circuit breaker breaking time, Backup Protection relays operating time including lock-out relay, Tolerance of operating time of relay and circuit breaker

K_{sc} : Constant depending on initial temperature, final temperature and material of conductor insulation. This factor is obtained from following formula

$$K_{sc} = K \times \sqrt{\log_e \frac{(T_f+\beta)}{(T_i+\beta)}} \qquad (7)$$

Where:

K : Constant for the material of the conductor

T_f : Final Temperature (°C).

T_i : Initial Temperature (°C).

β : Reciprocal of the temperature coefficient of resistance (α) of the conductor Per degree Celsius at 0°C)

T_f is equal to 250°C for XLPE and 160°C for PVC as well as Ti is equal to 90°C for XLPE and 70°C for PVC. K & β are obtained from table below:

Conductor Material Specification

Material	k	β
Copper	226	234.5
Aluminium	148	228

Therefore K_{sc} is 115 for PVC insulated copper wire and 143 for XLPE insulated copper wire.
When cable's protected by fuse, the following formula can be used instead:

$$S_{min} = \frac{\sqrt{I^2 \times t}}{K_{sc}} \quad (8)$$

Where I^2t is let through energy of fuse, and shall be considered from fuse manufacturer's curves.

8.0 SHORT CIRCUIT CALCULATION

8.1 Minimum Cable Size for MV Feeder

11 & 3.3 KV Cable

Voltage Bus Connected	Momentary Fault Current RMS (KA) ("I")	Clearing Time(S)
11 KV Feeder (Incoming)	25	0.5
11 KV Feeder (Outgoing)	25	0.3

According to Standard IEEE 242 ITEM 7.2.7, the maximum capability of a circuit breaker to withstand the effects of short circuit flow for a stated period, typically 0.5 s or less without opening.
According to IPS-E-EL-100(1) ITEM 7.7.2.3, for medium voltage power cables controlled by circuit breaker, the minimum fault clearance time shall be considered 0.3 seconds.
Considering the above, minimum cable size is obtained from the following formula:

For incoming feeder: $S = \sqrt{t} \times I / k = \sqrt{0.5} \times 25 / 143 \sim 120\ mm^2$

Therefore, the minimum cable size for 11 kV incoming feeders shall be 120 mm^2 which are next largest cable sizes in consideration of above calculation.

For 11 & 3.3 KV outgoing feeder: $S = \sqrt{t} \times I / k = \sqrt{0.3} \times 25 / 143 \sim 95\ mm^2$

Therefore, the minimum cable size for 11 kV outgoing feeders shall be 95 mm^2 which are next largest cable sizes in consideration of above calculation.

Additionally, since fault current for outgoing feeders with HRC fuse contactor shall be cleared immediately, minimum cable size for these feeders shall be considered 50 mm^2 for motors.

8.2 Minimum Cable Size for LV Feeder (0.4 KV)

For 0.4kV incoming feeders (with ACB): S =√t x I/ k=√0.5 x 50 / 143 ~ 240 mm^2

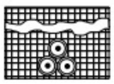
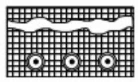
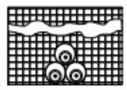
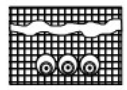
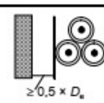
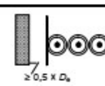
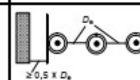
Therefore, the minimum cable size for LV ACB type incoming feeders shall be 240 mm^2

9.0 DE-RATING FACTOR CALCULATION

9.1 De-Rating Factor for MV Cables

For XLPE Insulation (in 52 °C air temperature and 35°C soil temperature with 2.5 K.w/m soil thermal resistivity), Current carrying capacity for MV cables are as follows based on IEC60502-2 Table B.2 and B6:

Table B.2 – Current ratings for single-core cables with XLPE insulation – Rated voltage 3,6/6 kV to 18/30 kV * – Copper conductor

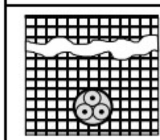
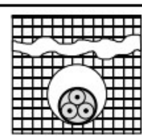
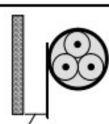
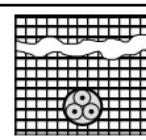
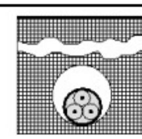
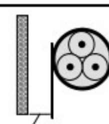
Nominal area of conductor	Buried direct in the ground		In single-way ducts		In air		
	Trefoil	Flat spaced	Trefoil ducts	Flat touching ducts	Trefoil	Flat touching	Flat spaced
							
mm^2	A	A	A	A	A	A	A
16	109	113	103	104	125	128	150
25	140	144	132	133	163	167	196
35	166	172	157	159	198	203	238
50	196	203	186	188	238	243	286
70	239	246	227	229	296	303	356
95	285	293	271	274	361	369	434
120	323	332	308	311	417	426	500
150	361	366	343	347	473	481	559
185	406	410	387	391	543	550	637
240	469	470	447	453	641	647	745
300	526	524	504	510	735	739	846
400	590	572	564	571	845	837	938

Maximum conductor temperature	90 °C
Ambient air temperature	30 °C
Ground temperature	20 °C
Depth of laying	0,8 m
Thermal resistivity of soil	1,5 K·m/W
Thermal resistivity of earthenware ducts	1,2 K·m/W
Screens bonded at both ends.	

* Current rating calculated for cables having a rated voltage of 6/10 kV.

According to page 50 of Attachment 1.

Table B.6 – Current rating for three-core XLPE insulated cables – Rated voltage 3,6/6 kV to 18/30 kV * – Copper conductor, armoured and unarmoured

Nominal area of conductor	Unarmoured			Armoured		
	Buried direct in ground	In a buried duct	In air	Buried direct in ground	In a buried duct	In air
			 ≥ 0,3 × D_e			 ≥ 0,3 × D_e
mm^2	A	A	A	A	A	A
16	101	87	109	101	88	110
25	129	112	142	129	112	143
35	153	133	170	154	134	172
50	181	158	204	181	158	205
70	221	193	253	220	194	253
95	262	231	304	263	232	307
120	298	264	351	298	264	352
150	334	297	398	332	296	397
185	377	336	455	374	335	453
240	434	390	531	431	387	529
300	489	441	606	482	435	599
400	553	501	696	541	492	683

Maximum conductor temperature	90 °C
Ambient air temperature	30 °C
Ground temperature	20 °C
Depth of laying	0,8 m
Thermal resistivity of soil	1,5 K·m/W
Thermal resistivity of earthenware ducts	1,2 K·m/W

* Current rating calculated for cables having a rated voltage of 6/10 kV.

According to page 54 of Attachment 1.

9.2 De-Rating Factor for MV Cables in Air

According to section 9.1, coefficient f1 & f2 will be Calculated According to IEC 60502-2 Table B.10 and B.22 & B.23 respectively for XLPE (in 48 °C air temperature and 20°C soil temperature with 2.5 K.w/m soil thermal resistivity),

Table B.10 – Correction factors for ambient air temperatures other than 30 °C

Maximum conductor temperature °C	Ambient air temperature °C							
	20	25	35	40	45	50	55	60
90	1,08	1,04	0,96	0,91	0,87	0,82	0,76	0,71

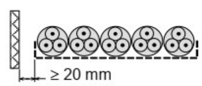
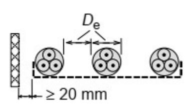
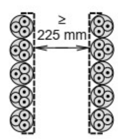
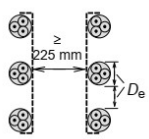
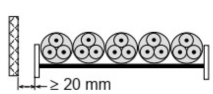
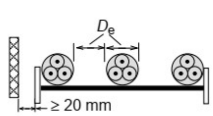
According to table 8 of page 56 of Attachment 1

According to Linear Interpolation ambient air correction factor will be:

$$y - y_1 = \left(\frac{y_1 - y_2}{x_1 - x_2}\right)(x - x_1)$$

$$y - 0.82 = \left(\frac{0.82 - 0.87}{50 - 4}\right)(48 - 50) \qquad (9)$$

Table B.22 – Reduction factors for groups of more than one multi-core cable in air – To be applied to the current-carrying capacity for one multi-core cable in free air

Method of installation		Number of trays	Number of cables					
			1	2	3	4	6	9
Cables on perforated trays	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	–
Cables on vertical perforated trays	 Touching	1	1,00	0,88	0,82	0,78	0,73	0,72
		2	1,00	0,88	0,81	0,76	0,71	0,70
	 Spaced	1	1,00	0,91	0,89	0,88	0,87	–
		2	1,00	0,91	0,88	0,87	0,85	–
Cables on ladder supports, cleats, etc.	Touching 	1	1,00	0,87	0,82	0,80	0,79	0,78
		2	1,00	0,86	0,80	0,78	0,76	0,73
		3	1,00	0,85	0,79	0,76	0,73	0,70
	Spaced 	1	1,00	1,00	1,00	1,00	1,00	–
		2	1,00	0,99	0,98	0,97	0,96	–
		3	1,00	0,98	0,97	0,96	0,93	–

NOTE 1 Values given are averages for the cable types and range of conductor sizes considered. The spread of values is generally less than 5 %.

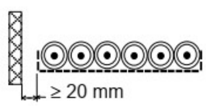
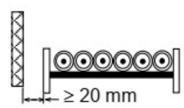
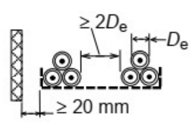
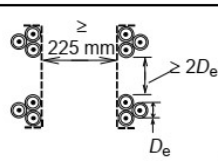
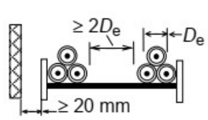
NOTE 2 Factors apply to single layer groups of cables as shown above and do not apply when cables are installed in more than one layer touching each other. Values for such installations may be significantly lower and must be determined by an appropriate method.

NOTE 3 Values are given for vertical spacings between trays of 300 mm and at least 20 mm between trays and wall. For closer spacing, the factors should be reduced.

NOTE 4 Values are given for horizontal spacing between trays of 225 mm with trays mounted back to back. For closer spacing, the factors should be reduced.

According to table 20 of page 62 of Attachment 1.

Table B.23 – Reduction factors for groups of more than one circuit of single-core cables (Note 2) – To be applied to the current-carrying capacity for one circuit of single-core cables in free air

Method of installation		Number of trays	Number of three-phase circuits (Note 5) 1	2	3	Use as a multiplier to rating for
Perforated trays (Note 3)	Touching 	1	0,98	0,91	0,87	Three cables in horizontal formation
		2	0,96	0,87	0,81	
		3	0,95	0,85	0,78	
Ladder supports, cleats etc. (Note 3)	Touching 	1	1,00	0,97	0,96	Three cables in horizontal formation
		2	0,98	0,93	0,89	
		3	0,97	0,90	0,86	
Perforated trays (Note 3)		1	1,00	0,98	0,96	Three cables in trefoil formation
		2	0,97	0,93	0,89	
		3	0,96	0,92	0,86	
Vertical perforated trays (Note 4)	 Spaced	1	1,00	0,91	0,89	
		2	1,00	0,90	0,86	
Ladder supports, cleats, etc. (Note 3)		1	1,00	1,00	1,00	
		2	0,97	0,95	0,93	
		3	0,96	0,94	0,90	

NOTE 1 Values given are averages for the cable types and range of conductor sizes considered. The spread of values is generally less than 5 %.

NOTE 2 Factors are given for single layers of cables (or trefoil groups) as shown in the table and do not apply when cables are installed in more than one layer touching each other. Values for such installations may be significantly lower and should be determined by an appropriate method.

NOTE 3 Values are given for vertical spacings between trays of 300 mm. For closer spacing, the factors should be reduced.

NOTE 4 Values are given for horizontal spacing between trays of 225 mm with trays mounted back to back. For closer spacing, the factors should be reduced.

NOTE 5 For circuits having more than one cable in parallel per phase, each three phase set of conductors should be considered as a circuit for the purpose of this table.

According to table 21 of page 63 of Attachment 1.

MV Above Ground Cable

Multi Core	Air Temperature Table B.10 of IEC 60502-2	f1	**0.80**
	Grouping cable Table B.22 of IEC 60502-2	f2	**0.70**
	Result	f1×f2	**0.56**
Single Core	Air Temperature Table B.10 of IEC 60502-2	f1	**0.80**
	Grouping cable Table B.23 of IEC 60502-2	f2	0.86
	Result	f1×f2	**0.69**

According to formula (9), f1 is 0.80.

- Grouping factor (f2) for multi core MV cables will be achieved based on touching cables on 3 number of ladders & 9 number of cables in each one.
- Grouping factor (f2) for single core MV cables will be achieved based on touching cables on 3 number of ladders & 3 number of three- phase circuits.

9.3 De-Rating Factor for MV Cables in Ground

According to section 8.1, coefficient f1, f2, f3 & f4 will be Calculate According to IEC 60502-2 Table B.11 and B.22 & 23 respectively:

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Table B.11 – Correction factors for ambient ground temperatures other than 20 °C

Maximum conductor temperature °C	Ambient ground temperature °C							
	10	15	25	30	35	40	45	50
90	1,07	1,04	0,96	0,93	0,89	0,85	0,80	0,76

According to table 9 of page 56 of Attachment 1

Table B.12 – Correction factors for depths of laying other than 0,8 m 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
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

According to table 10 of page 56 of Attachment 1

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Table B.14 – Correction factors for soil thermal resistivities other than 1,5 K·m/W for direct buried single-core cables

Nominal area of conductor mm²	Values of soil thermal resistivity K·m/W						
	0,7	0,8	0,9	1	2	2,5	3
16	1,29	1,24	1,19	1,15	0,89	0,82	0,75
25	1,30	1,25	1,20	1,16	0,89	0,81	0,75
35	1,30	1,25	1,21	1,16	0,89	0,81	0,75
50	1,32	1,26	1,21	1,16	0,89	0,81	0,74
70	1,33	1,27	1,22	1,17	0,89	0,81	0,74
95	1,34	1,28	1,22	1,18	0,89	0,80	0,74
120	1,34	1,28	1,22	1,18	0,88	0,80	0,74
150	1,35	1,28	1,23	1,18	0,88	0,80	0,74
185	1,35	1,29	1,23	1,18	0,88	0,80	0,74
240	1,36	1,29	1,23	1,18	0,88	0,80	0,73
300	1,36	1,30	1,24	1,19	0,88	0,80	0,73
400	1,37	1,30	1,24	1,19	0,88	0,79	0,73

According to table 12 of page 57 of Attachment 1

Table B.16 – Correction factors for soil thermal resistivities other than 1,5 K·m/W for direct buried three-core cables

Nominal area of conductor	Values of soil thermal resistivity K•m/W						
mm²	0,7	0,8	0,9	1	2	2,5	3
16	1,23	1,19	1,16	1,13	0,91	0,84	0,78
25	1,24	1,20	1,16	1,13	0,91	0,84	0,78
35	1,25	1,21	1,17	1,13	0,91	0,83	0,78
50	1,25	1,21	1,17	1,14	0,91	0,83	0,77
70	1,26	1,21	1,18	1,14	0,90	0,83	0,77
95	1,26	1,22	1,18	1,14	0,90	0,83	0,77
120	1,26	1,22	1,18	1,14	0,90	0,83	0,77
150	1,27	1,22	1,18	1,15	0,90	0,83	0,77
185	1,27	1,23	1,18	1,15	0,90	0,83	0,77
240	1,28	1,23	1,19	1,15	0,90	0,83	0,77
300	1,28	1,23	1,19	1,15	0,90	0,82	0,77
400	1,28	1,23	1,19	1,15	0,90	0,82	0,76

According to table 14 of page 58 of Attachment 1

Table B.18 – Correction factors for groups of three-core cables in horizontal formation laid direct in the ground

Number of cables in group	Spacing between cable centres mm				
	Touching	200	400	600	800
2	0,80	0,86	0,90	0,92	0,94
3	0,69	0,77	0,82	0,86	0,89
4	0,62	0,72	0,79	0,83	0,87
5	0,57	0,68	0,76	0,81	0,85
6	0,54	0,65	0,74	0,80	0,84
7	0,51	0,63	0,72	0,78	0,83
8	0,49	0,61	0,71	0,78	
9	0,47	0,60	0,70	0,77	–
10	0,46	0,59	0,69	–	–
11	0,45	0,57	0,69	–	–
12	0,43	0,56	0,68	–	–

Table B.19 – Correction factors for groups of three-phase circuits of single-core cables laid direct in the ground

Number of cables in group	Spacing between group centres mm				
	Touching	200	400	600	800
2	0,73	0,83	0,88	0,90	0,92
3	0,60	0,73	0,79	0,83	0,86
4	0,54	0,68	0,75	0,80	0,84
5	0,49	0,63	0,72	0,78	0,82
6	0,46	0,61	0,70	0,76	0,81
7	0,43	0,58	0,68	0,75	0,80
8	0,41	0,57	0,67	0,74	–
9	0,39	0,55	0,66	0,73	–
10	0,37	0,54	0,65	–	–
11	0,36	0,53	0,64	–	–
12	0,35	0,52	0,64	–	–

According to table 16 & 17 of page 60 of Attachment 1

MV Under Ground Cable

Items	De-rates	Three core	Single core
Soil Temperature Table B.11 of IEC 60502-2	f1	0.89	0.89
Soil thermal resistivity Table B.16 (3 core) Table B.14 (1 core) of IEC 60502-2	f2	0.83	0.8
Grouping of cables Table B.18 (3 core) Table B.19 (1 core) of IEC 60502-2	f3	0.77	0.73
Depth of laying cables Table B.12 of IEC 60502-2	f4	0.98	0.97
Result Multiple of above values	f1×f2×f3×f4	0.56	0.5

Grouping factor (f3) is based on 3 number of cable with minimum distance 15 cm based on typical drawing as per IPS standard.

9.4 De-Rating Factor for LV Cables In Air

According to section 8.1, coefficient f1 & f2 will be Calculate According to IEC 60364-5-52:

60364-5-52 © IEC:2009 – 53 –

Table B.52.14 – Correction factor for ambient air temperatures other than 30 °C to be applied to the current-carrying capacities for cables in the air

Ambient temperature[a] °C	Insulation			
	PVC	XLPE and EPR	Mineral[a]	
			PVC covered or bare and exposed to touch 70 °C	Bare not exposed to touch 105 °C
10	1,22	1,15	1,26	1,14
15	1,17	1,12	1,20	1,11
20	1,12	1,08	1,14	1,07
25	1,06	1,04	1,07	1,04
30	1,00	1,00	1,00	1,00
35	0,94	0,96	0,93	0,96
40	0,87	0,91	0,85	0,92
45	0,79	0,87	0,78	0,88
50	0,71	0,82	0,67	0,84
55	0,61	0,76	0,57	0,80
60	0,50	0,71	0,45	0,75
65	–	0,65	–	0,70
70	–	0,58	–	0,65
75	–	0,50	–	0,60
80	–	0,41	–	0,54
85	–	–	–	0,47
90	–	–	–	0,40
95	–	–	–	0,32

[a] For higher ambient temperatures, consult the manufacturer.

According to table 9 of page 110 of Attachment 2

Table B.52.5 – Current-carrying capacities in amperes for methods of installation in Table B.52.1 – XLPE or EPR insulation, three loaded conductors/copper or aluminium – Conductor temperature: 90 °C, ambient temperature: 30 °C in air, 20 °C in ground

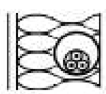
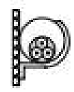
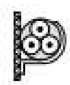
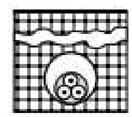
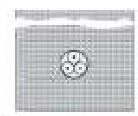
Nominal cross-sectional area of conductor mm²	Installation methods of Table B.52.1						
	A1	A2	B1	B2	C	D1	D2
							
1	2	3	4	5	6	7	8
Copper							
1,5	17	16,5	20	19,5	22	21	23
2,5	23	22	28	26	30	28	30
4	31	30	37	35	40	36	39
6	40	38	48	44	52	44	49
10	54	51	66	60	71	58	65
16	73	68	88	80	96	75	84
25	95	89	117	105	119	96	107
35	117	109	144	128	147	115	129
50	141	130	175	154	179	135	153
70	179	164	222	194	229	167	188
95	216	197	269	233	278	197	226
120	249	227	312	268	322	223	257
150	285	259	342	300	371	251	287
185	324	295	384	340	424	281	324
240	380	346	450	398	500	324	375
300	435	396	514	455	576	365	419

Table B.52.20 – Reduction factors for group of more than one multi-core cable to be applied to reference current-carrying capacities for multi-core cables in free air – Method of installation E in Tables B.52.8 to B.52.13

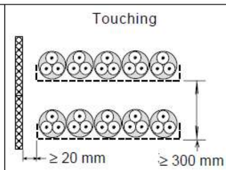
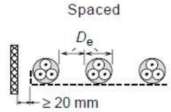
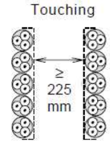
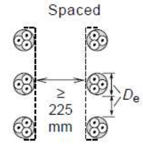
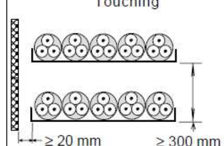
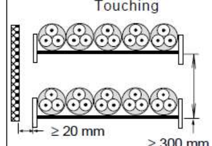
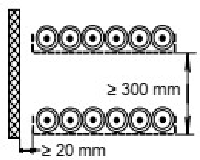
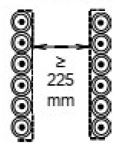
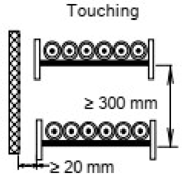
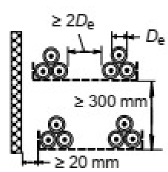
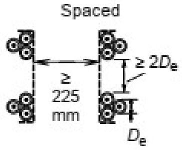
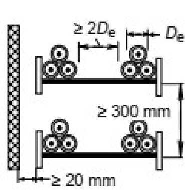
Method of installation in Table A.52.3			Number of trays or ladders	Number of cables per tray or ladder					
				1	2	3	4	6	9
Perforated cable tray systems (note 3)	31	Touching 	1	1,00	0,88	0,82	0,79	0,76	0,73
			2	1,00	0,87	0,80	0,77	0,73	0,68
			3	1,00	0,86	0,79	0,76	0,71	0,66
			6	1,00	0,84	0,77	0,73	0,68	0,64
		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	–
Vertical perforated cable tray systems (note 4)	31	Touching 	1	1,00	0,88	0,82	0,78	0,73	0,72
			2	1,00	0,88	0,81	0,76	0,71	0,70
		Spaced 	1	1,00	0,91	0,89	0,88	0,87	–
			2	1,00	0,91	0,88	0,87	0,85	–
Unperforated cable tray systems	31	Touching 	1	0,97	0,84	0,78	0,75	0,71	0,68
			2	0,97	0,83	0,76	0,72	0,68	0,63
			3	0,97	0,82	0,75	0,71	0,66	0,61
			6	0,97	0,81	0,73	0,69	0,63	0,58
Cable ladder systems, cleats, etc. (note 3)	32 33 34	Touching 	1	1,00	0,87	0,82	0,80	0,79	0,78
			2	1,00	0,86	0,80	0,78	0,76	0,73
			3	1,00	0,85	0,79	0,76	0,73	0,70
			6	1,00	0,84	0,77	0,73	0,68	0,64

Table B.52.21 – Reduction factors for groups of one or more circuits of single-core cables to be applied to reference current-carrying capacity for one circuit of single-core cables in free air – Method of installation F in Tables B.52.8 to B.52.13

Method of installation in Table A.52.3			Number of trays or ladders	Number of three-phase circuits per tray or ladder 1	2	3	Use as a multiplier to current-carrying capacity for
Perforated cable tray systems (note 3)	31	Touching  	1 2 3	0,98 0,96 0,95	0,91 0,87 0,85	0,87 0,81 0,78	Three cables in horizontal formation
Vertical perforated cable tray systems (note 4)	31	Touching  	1 2	0,96 0,95	0,86 0,84	– –	Three cables in vertical formation
Cable ladder systems, cleats, etc. (note 3)	32 33 34	Touching  	1 2 3	1,00 0,98 0,97	0,97 0,93 0,90	0,96 0,89 0,86	Three cables in horizontal formation
Perforated cable tray systems (note 3)	31	 	1 2 3	1,00 0,97 0,96	0,98 0,93 0,92	0,96 0,89 0,86	
Vertical perforated cable tray systems (note 4)	31	Spaced  	1 2	1,00 1,00	0,91 0,90	0,89 0,86	Three cables in trefoil formation
Cable ladder systems, cleats, etc. (note 3)	32 33 34	 	1 2 3	1,00 0,97 0,96	1,00 0,95 0,94	1,00 0,93 0,90	

According to table 16 of page 116 of Attachment 2.

LV Above Ground Cable (In Air)

Cable Type	Verified Tables	De-rate	XLPE	PVC
Multi Core	Air Temperature Table B.52-14 of IEC 60364	f1	**0.80**	**0.67**
	Grouping cable Table B.52-20 of IEC 60364	f2	0.73	0.73
	Result	f1×f2	**0.58**	**0.49**
Single Core	Air Temperature Table B.52-14 of IEC 60364	f1	**0.80**	**0.67**
	Grouping Cable Table B.52-21 of IEC 60364	f2	0.86	0.86
	Result	f1×f2	**0.69**	**0.58**

F1: According to table B.52-14 & based on linear interpolation, 0.80 & 0.67 derived for XLPE & PVC cable.

F2: According to table B.52-20, derating factor for 6 number of cables in 3 layer ladder is 0.73 for multi core while this factor is 0.86 for single core cable based on B.52-21 table.

9.5 De-Rating Factor for Underground LV Cables

Table B.52.15 – Correction factors for ambient ground temperatures other than 20 °C to be applied to the current-carrying capacities for cables in ducts in the ground

Ground temperature °C	Insulation	
	PVC	XLPE and EPR
10	1,10	1,07
15	1,05	1,04
20	1,00	1,00
25	0,95	0,96
30	0,89	0,93
35	0,84	0,89
40	0,77	0,85
45	0,71	0,80
50	0,63	0,76
55	0,55	0,71
60	0,45	0,65
65	–	0,60
70	–	0,53
75	–	0,46
80	–	0,38

According to table 10 of page 111 of Attachment 2

Table B.52.16 – Correction factors for cables buried direct in the ground or in buried ducts for soil thermal resistivities other than 2,5 K·m/W to be applied to the current-carrying capacities for reference method D

Thermal resistivity, K·m/W	0,5	0,7	1	1,5	2	2,5	3
Correction factor for cables in buried ducts	1,28	1,20	1,18	1,1	1,05	1	0,96
Correction factor for direct buried cables	1,88	1,62	1,5	1,28	1,12	1	0,90

NOTE 1 The correction factors given have been averaged over the range of conductor sizes and types of installation included in Tables B.52.2 to B.52.5. The overall accuracy of correction factors is within ±5 %.

NOTE 2 The correction factors are applicable to cables drawn into buried ducts; for cables laid direct in the ground the correction factors for thermal resistivities less than 2,5 K·m/W will be higher. Where more precise values are required they may be calculated by methods given in the IEC 60287 series.

NOTE 3 The correction factors are applicable to ducts buried at depths of up to 0,8 m.

NOTE 4 It is assumed that the soil properties are uniform. No allowance had been made for the possibility of moisture migration which can lead to a region of high thermal resistivity around the cable. If partial drying out of the soil is foreseen, the permissible current rating should be derived by the methods specified in the IEC 60287 series.

Table B.52.18 – Reduction factors for more than one circuit, cables laid directly in the ground – Installation method D2 in Tables B.52.2 to B.52.5 – Single-core or multi-core cables

Number of circuits	Cable to cable clearance[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
7	0,45	0,51	0,59	0,67	0,76
8	0,43	0,48	0,57	0,65	0,75
9	0,41	0,46	0,55	0,63	0,74
12	0,36	0,42	0,51	0,59	0,71
16	0,32	0,38	0,47	0,56	0,38
20	0,29	0,35	0,44	0,53	0,66

[a] Multi-core cables

[a] Single-core cables

NOTE 1 Values given apply to an installation depth of 0,7 m and a soil thermal resistivity of 2,5 K·m/W. They are average values for the range of cable sizes and types quoted for Tables B.52.2 to B.52.5. The process of averaging, together with rounding off, can result in some cases in errors up to ±10 %. (Where more precise values are required they may be calculated by methods given in IEC 60287-2-1.)

NOTE 2 In case of a thermal resistivity lower than 2,5 K·m/W the corrections factors can, in general, be increased and can be calculated by the methods given in IEC 60287-2-1.

NOTE 3 If a circuit consists of *m* parallel conductors per phase, then for determining the reduction factor, this circuit should be considered as *m* circuits.

According to table 13 of page 113 of Attachment 2

LV Under Ground Cable

Verified Tables	De-rates	XLPE	PVC
Soil Temperature Table B.52.15 of IEC 60364-5-52	f1	0.89	**0.84**
Soil thermal resistivity Table B.52.16	f2	1	1
Grouping of cables Table B.52.18	f3	**0.55**	**0.55**
Depth of laying cables Table B.12 of IEC 60502-2	f4	0.98	0.98
Result Multiple of above values	f1×f2×f3×f4	**0.48**	**0.45**

F1: According to table B.52-15 & soil temperature 52°C, F1 for XLPE will be 0.89 and for PVC will be 0.84.

F2: this factor is 1 based on table B.52.16

F3 is 0.55 based on table B.52-18 for 6 number of circuit with one cable diameter.

F4; depth of laying is 1 meter.

10.0 RESULT SUMMARY

Cable Type	Verified Tables	XLPE	PVC
Multi Core	MV Above Ground Cable	0.56	-
	MV Under Ground Cable	0.56	-
	LV Above Ground Cable	0.58	0.49
	LV Under Ground Cable	0.48	0.45
Single Core	MV Above Ground Cable	0.69	-
	MV Under Ground Cable	0.50	-
	LV Above Ground Cable	0.69	0.58
	LV Under Ground Cable	0.48	0.45

11.0 CABLE RESISTANCE

According to ABHAR catalogue (Page 26), cable resistance is as below:

Cable Resistance for XLPE MV Cable	
X-Section	3 Core
35	0.668+j0.14

Cable Resistance for XLPE MV Cable

X-Section	3 Core
50	0.494+j0.13
70	0.342+j0.123
95	0.247+j0.117
120	0.196+j0.111
150	0.159+j0.108
185	0.1277+j0.104
240	0.098+j0.100
300	0.0791+j0.097
400	-

Cable Resistance for LV Cable

	XLPE		PVC	
X-Section	1 Core	3 Core (Page 32)	1 Core	3 Core
1.5	-	15.43+j0.103	-	-
2.5	-	9.45+j0.095	-	-
4	-	5.88+j0.09	-	-
6	-	3.93+j0.087	-	-
10	-	2.33+j0.083	-	-
16	1.47+j0.261	1.47+j0.081	1.38+j0.146	1.38+j0.087
25	0.927+j0.248	0.927+j0.081	0.87+j0.137	0.87+j0.086
35	0.668+j0.239	0.669+j0.079	0.627+j0.131	0.627+j0.083
50	0.494+j0.227	0.494+j0.075	0.463+j0.123	0.464+j0.08
70	0.342+j0.217	0.343+j0.075	0.321+j0.116	0.322+j0.078
95	0.247+j0.208	0.247+j0.072	0.232+j0.111	0.232+j0.077
120	0.196+j0.201	0.197+j0.072	0.184+j0.107	0.185+j0.075
150	0.159+j0.196	0.16+j0.072	0.15+j0.104	0.15+j0.075
185	0.1278+j0.19	0.129+j0.072	0.12+j0.102	0.1212+j0.075
240	0.0981+j0.183	0.0996+j0.071	0.092+j0.099	0.093+j0.074
300	0.0792+j0.178	0.081+j0.071	0.074+j0.097	0.076+j0.074
400	0.0632+j0.171	-	0.059+j0.095	-

12.0 CABLE SIZING EXAMPLE

12.1 Gas Compressor C-2101

a) Current Capacity

According to load list (BK-GCS-PEDCO-120-EL-LI-0001), the rated power of each C-2101 is 1250 kW:

Rated Power: 1250 kW

Voltage: 11 kV

Power Factor: 0.75

Efficiency: 0.95

$$I_l = \frac{1250}{\sqrt{3} \times 11 \times 0.75 \times 0.95} = 92.08\ A$$

Since this cable is buried, it is considered as an under-ground cable which the de-rating factor is specified above and being 0.56. Therefore the rating current will be:

$$I_r = \frac{I_l}{f_{UG\_MV}} = \frac{92.08}{0.56} = 164.4\ A$$

According to ABHAR catalogue, in page 54 of attachment 1, the minimum size is 3Cx50 mm^2 with 181A current-carrying capacity for compressor but based on section 8.3, the minimum cross section will be 3Cx95 mm^2.

b) Voltage Drop at Normal Operation

According to section 8.2, voltage drop for MV motor shall be lower than 3.25%. So the minimum cable size that satisfied this condition is derived from equation (3), maximum cable length 350m and Cosφ =0.75 (Sin φ =0.64):

$$\Delta u = \frac{\sqrt{3}LI(RCos\phi + XSin\phi)}{U_N} \times 100 = \frac{\sqrt{3} \times 0.35 \times 92.08 \times (0.247 \times 0.75 + 0.117 \times 0.64)}{11 \times 10^3} \times 100 = 0.13\ \% < 3.25\ \%$$

c) Voltage Drop at Starting

According to section 8.2, voltage drop for MV motor at starting shall be lower than 15%. So the minimum cable size that satisfied this condition is derived from equation (3), maximum cable length 350m and Cosφ =0.15 (Sin φ =0.99):

$$\Delta u = \frac{\sqrt{3}LI(RCos\phi + XSin\ \ )}{U_N} \times 100 = \frac{\sqrt{3} \times 0.35 \times 6 \times 92.08 \times (0.247 \times 0.15 + 0.117 \times 0.99)}{11 \times 10^3} \times 100 = 0.47\ \% < 15\ \%$$

So, the cable size, 3Cx95 mm2, can sufficiently be used for this feeder.

12.2 LV Transformer “GCS-TR-001” Primary Side

a) Current Capacity

$S = 1250\ KVA$

$V = 11\ KV$

$PF = 0.8$

$$I_l = \frac{S}{\sqrt{3} \times V} = \frac{1250}{\sqrt{3} \times 11} = 65.6\ A$$

Since this cable is aboveground (laid on tray/ladder) * three core, the de-rating factor is 0.56. Therefore the rating current will be:

$$I_r = \frac{I_l}{f_{UG\_MV}} = \frac{65.6}{0.56} = 117.14\ A$$

According to ABHAR catalogue, in page 54 of attachment 1, the minimum size is 3Cx50 mm^2 with 205A current-carrying capacity for transformer but based on section 8.3, the minimum cross section will be 3Cx95 mm^2.

b) Voltage Drop

According to section 8.2, voltage drop for LV transformer shall be lower than 1%. So the minimum cable size that satisfied this condition is derived from equation (3), maximum cable length 100m and Cosφ =0.8 (Sin φ =0.6):

$$\Delta u = \frac{\sqrt{3}LI(RCos\phi + XSin\phi)}{U_N} \times 100 = \frac{\sqrt{3} \times 0.1 \times 65.6 \times (0.247 \times 0.8 + 0.117 \times 0.6)}{11 \times 10^3} \times 100 = 0.027\ \% < 1\ \%$$

So, the cable size, 3Cx95 mm^2, can sufficiently be used for this feeder.

12.3 LV Transformer “GCS-TR-001” Secondary Side

a) Current Capacity

$S = 1250\ KVA$

$V = 0.4\ KV$

$PF = 0.8$

$$I_l = \frac{S50}{\sqrt{3} \times V} = \frac{1250}{\sqrt{3} \times 0.4} = 1804\ A$$

Since this cable is aboveground, the de-rating factor is specified 0.69. Therefore the rating current will be:

$$I_r = \frac{I_l}{f_{UG_{LV}}} = \frac{1804}{0.69} = 2614\ A$$

According to ABHAR catalogue, in page 108 of attachment 2, the minimum size is 4x1Cx300 mm^2 with 2614A current-carrying capacity for transformer is sufficient.

b) Voltage Drop

According to section 8.2, voltage drop for LV transformer shall be lower than 1%. So the minimum cable size that satisfied this condition is derived from equation (3), maximum cable length 33m and Cosφ =0.8 (Sin φ =0.6):

$$\Delta u = \frac{\sqrt{3}LI(RCos\phi + XSin\phi)}{U_N} \times 100 = \frac{\sqrt{3}\times 0.033\times 1804\times(0.0198\times 0.8+0.0445\times 0.6)}{400} \times 100 = 1\ \%$$

According to above calculation, the cables for secondary side of LV transformer will be 14x1Cx300.

12.4 Fire Water Pump P-2301 A

d) Current Capacity

According to load list (BK-GCS-PEDCO-120-EL-LI-0001), the rated power of each P-2301 is 280 kw:

Rated Power: 280 kw

Voltage: 3.3 kv

Power Factor: 0.88

Efficiency: 0.93

$$I_l = \frac{280}{\sqrt{3}\times 3.3\times 0.88\times 0.93} = 60\ A$$

Since this cable is buried, it is considered as an under-ground cable which the de-rating factor is specified above and being 0.56. Therefore the rating current will be:

$$I_r = \frac{I_l}{f_{UG\_MV}} = \frac{60}{0.56} = 107\ A$$

According to ABHAR catalogue, in page 54 of attachment 1, the minimum size is 3Cx25 mm^2 with 129A current-carrying capacity for compressor but based on section 8.3, the minimum cross section will be 3Cx95 mm^2.

e) Voltage Drop at Normal Operation

According to section 8.2, voltage drop for MV motor shall be lower than 3.25%. So the minimum cable size that satisfied this condition is derived from equation (3), maximum cable length 100m and Cosφ =0.88 (Sin φ =0.47):

$$\Delta u = \frac{\sqrt{3}LI(RCos\phi + XSin\phi)}{U_N} \times 100 = \frac{\sqrt{3}\times 0.1\times 107\times(0.247\times 0.88+0.117\times 0.47)}{3.3\times 10^3} \times 100 = 0.15\ \% < 3.25\ \%$$

f) Voltage Drop at Starting

According to section 8.2, voltage drop for MV motor at starting shall be lower than 15%. So the minimum cable size that satisfied this condition is derived from equation (3), maximum cable length 100m and Cosφ =0.2 (Sin φ =0.98):

$$\Delta u = \frac{\sqrt{3}LI(RCos\phi + XSin\phi)}{U_N} \times 100 = \frac{\sqrt{3}\times 0.1\times 6\times 107\times(0.247\times 0.2+0.117\times 0.98)}{3.3\times 10^3} \times 100 = 0.55\ \% < 15\ \%$$

So, the cable size, 3Cx95 mm^2, can sufficiently be used for this feeder.