

Analysis of Power Cable Sizing and Voltage Drop in the Upgrading Stasiun Pengumpul Puspa Asri 2 Project

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Abstract

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The upgrading of oil and gas production facilities requires an electrical power distribution system that is reliable, safe, and compliant with voltage quality limits. This article discusses power cable sizing and voltage drop evaluation for the Puspa Asri Gathering Station Phase 2 Upgrading Project in Jambi, based on engineering documents for calculating cable sizing and voltage drop in the Puspa Asri Phase 2 Collector Station Upgrading Project. The method includes load identification, full-load current calculation, determination of cable current-carrying capacity after temperature and grouping correction factors, verification of voltage drop under steady-state and motor-starting conditions, and assessment of thermal withstand capability under short-circuit conditions. The design criteria refer to IEC 60364-5-52 and related standards, with voltage drop limits of 2% for switchgear/MCC-to-switchgear/MCC routes, 5% for motor terminals under normal operating conditions, 15% during motor starting, and 3% for distribution panel feeders. The evaluation of 16 main cable routes shows that all selected cables satisfy the requirements for ampacity, voltage drop, and short-circuit withstand capability. The selected cable sizes range from 3C+E 4 mm² to 4C+E 95 mm², using a temperature correction factor of 0.91 and a grouping derating factor of 0.79 for aboveground installation. The Water Injection Pump C case study shows that the selected 4C+E 35 mm² cable has a corrected current-carrying capacity of 90.58 A, which is greater than the design current of 47.03 A, with a steady-state voltage drop of 1.33% and a motor-starting voltage drop of 3.95%. Therefore, the cable design is considered technically feasible to support reliable operation of the production facility.



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1. INTRODUCTION

The rapid development of the capital market has made stock price prediction one of the critical challenges in the fields of finance and artificial intelligence. Stock prices exhibit dynamic and non-linear characteristics and are influenced by various complex factors, including global economic conditions, monetary policies, corporate performance, and investor sentiment. This complexity makes stock price movements inherently difficult to predict accurately, thereby increasing the risk in investment decision-making. Therefore, there is a need for approaches that are capable of effectively capturing stock price patterns and adapting to market changes.

One of the stocks frequently used as a research object in Indonesia is Bank Central Asia Tbk, which is categorized as a blue-chip stock with high liquidity. Despite its relatively stable fundamentals, BBKA stock still exhibits significant price fluctuations and complex movement patterns. This indicates that even stocks with strong fundamentals remain challenging to predict, thus requiring more advanced analytical approaches.

In practice, stock price analysis is often conducted using technical indicators, one of which is the Moving Average (MA). Moving Average is a smoothing technique used to identify trends by reducing noise in price movements. In this study, MA5 and MA10 are employed, representing short-term and medium-term trends, respectively. The combination of these indicators is commonly used in crossover strategies to generate buy and sell signals. However, Moving Average has inherent limitations as it is a

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lagging indicator, resulting in delayed responses to actual price changes. This limitation can reduce its effectiveness, particularly in fast-moving and volatile markets.

2. LITERATURE REVIEW

Conductor selection in electrical distribution systems is not determined only by nominal current capacity, but also by voltage profile, power losses, and life-cycle cost [1],[2]. In power cable applications, ampacity is influenced by environmental thermal properties, installation method, and loading conditions [3],[6]. Voltage drop is another major design constraint because excessive voltage reduction may cause equipment to operate outside its permissible voltage range, especially for rotating machines and motor-driven loads [2],[7],[8]. Based on IEC 60364-5-52 and IEC 60364-4-43, low-voltage cable sizing shall satisfy current-carrying-capacity, voltage-drop, and short-circuit withstand requirements [13],[14].

Power cable sizing in electrical distribution systems is not only intended to satisfy load-current requirements but also to maintain voltage quality, improve system reliability, and minimize power losses throughout the service life of the installation. Appropriate conductor sizing contributes to both the technical and economic performance of industrial electrical systems while reducing long-term operational costs [1],[2]. Cable ampacity is affected by several installation-related factors, including ambient temperature, installation method, cable grouping arrangements, and surrounding thermal conditions. These factors may significantly reduce the actual current-carrying capability of a cable compared to its catalog rating and therefore must be considered through the application of appropriate derating factors [4]-[6],[13].

For motor loads, voltage-drop analysis is particularly important because terminal voltage directly affects motor starting performance. Increased cable length and excessive voltage drop may reduce motor acceleration capability and increase the possibility of unsuccessful motor starting under certain operating conditions [7]. Therefore, cable selection should simultaneously satisfy ampacity, voltage-drop, and short-circuit withstand requirements to ensure reliable system operation [3],[14].

Although numerous studies have investigated cable ampacity, voltage drop, and conductor sizing methods, most previous works focused on generalized design approaches or theoretical optimization models. Limited published studies discuss the practical implementation of IEC-based cable sizing for oil and gas production facilities under actual project conditions. Therefore, this study contributes to the existing literature by presenting a case study of cable-sizing implementation for the Puspa Asri 2 upgrading project using real engineering design data and project-specific operating constraints.

3. METHODOLOGY

This study uses a case study approach based on the project's technical documents prepared by the authors during the cable sizing and voltage drop calculation stages. The documents are used as the primary database and contain data on loads, cable routes, cable lengths, equipment ratings, power factors, efficiencies, cable catalog data, voltage drop limits, power drop factors, and selected cable sizes. Since the documents are unpublished engineering documents prepared by the authors, they are not included as formal references. The calculation process includes load identification, full-load current calculation, cable current capacity verification, voltage drop evaluation, and final cable selection based on manufacturer catalog data [13].

3.1 Research Flowchart

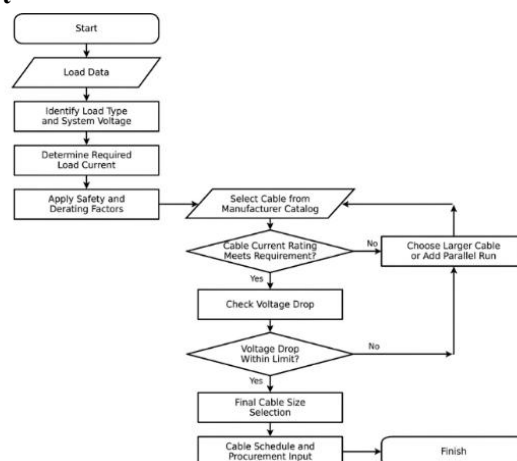


Figure 1. Flowchart of cable sizing and voltage drop evaluation.

As shown in Figure 1, the cable sizing process starts from load data identification and system voltage determination. The required load current is calculated and adjusted using safety and derating factors. The cable is then selected from the manufacturer catalog based on current rating, conductor size, cable cores, and installation conditions. If one of the criteria is not fulfilled, the cable size is revised by selecting a larger conductor size or adding a parallel cable run.

3.2 Design Criteria

3.2.1 Code and Standards

The calculation refers to IEC 60502, IEC 60228, IEC 60287, IEC 60034-2-1, IEC 60364-5-52, IEC 60364-4-43, PUIL/SNI and NFPA 70 as the main references for cable construction, conductor requirements, current rating calculation, rotating machine data, wiring system selection, overcurrent protection, and electrical safety [9],[15].

3.2.2 Cable Specification

The cable properties utilized in this analysis are based on manufacturer data from PT Sumi Indo Kabel Tbk, compliant with the IEC 60502-1 standard. The evaluated low-voltage power cables feature, the specifications of the cables used include a multi-core configuration with insulation and the use of metric cross-sectional (mm^2), as detailed in Table 1.

Tabel 1. General Technical Specifications

Parameter	Technical Description
Manufacturer	PT Sumi Indo Kabel Tbk
Voltage Rating (U_0 / U)	0.6/ 1 kV
Conductor Material	Plain Annealed Copper (Cu)
Insulation Material	XLPE (Cross-linked Polyethylene)
Outer Sheath	PVC Outer Sheath (Galvanized Steel Wire Armoured / GSWA if applicable)
Core Configuration	3C+E, 4C+E
Size	2,5 mm^2 – 300 mm^2

3.2.3 System and Operational Parameters

Table 2 presents the technical design constraints and operational specifications used as the primary basis for calculating power cable sizes. All parameters and values are based on applicable SNI and IEC standards to ensure reliable current-carrying capacity, thermal insulation safety, and the continuous operation of the electrical system. A detailed explanation of each parameter group, along with the relevant reference standards listed in Table 2.

Tabel 2. System and Operational Parameters

System / Operational Parameter	Reference Value
Nominal System Voltage (V_n)	380/ 400 V_{L-L} 220/ 230 V_{L-N}
Allowable Voltage Variation	$\pm 5\%$ Normal Operation $\pm 15\%$ Starting
Nominal Frequency	50 Hz ($\pm 2\%$)
Ambient Temperature	30°C - 40°C

The allowable voltage drop limits are established in accordance with IEC 60364-5-52, IEEE Std 141, PUIL 2011, and specific Oil & Gas Engineering Design Guidelines. The cable size is selected in such a way that the voltage drop in the cable is still within the limits determined in Table 3.

Table 3. Allowable voltage drop criteria [13].

Cable route / load category	Allowable voltage drop
Switchgear / MCC to Switchgear / MCC	2%
Switchgear / MCC to motor load terminal	5% steady state; 15% during motor starting
Switchgear / MCC to PDB / LP	3%
PDB / LP to load	2% for UPS AC / UPS DC
PDB to DC load / AC load	2%
Rectifier terminal to battery charger	2%
Overhead line	2%
Well transformer to well PDB	3%

The voltage-drop limits presented in Table 3 were adopted as design acceptance criteria during the engineering phase of the Puspa Asri 3 upgrading project. Different limits are assigned to different categories of electrical loads according to their operating characteristics. More stringent limits are applied to main distribution feeders to maintain voltage quality throughout the electrical network and prevent cumulative voltage reduction at the load terminals [13],[15].

For motor feeders, the allowable voltage drop is limited to 5% during normal operation and 15% during motor starting. The higher allowable value during starting conditions is necessary because induction motors typically draw several times their rated current, resulting in temporary voltage depression within the electrical network. However, sufficient voltage must remain available at the motor terminals to develop adequate starting torque and ensure successful motor acceleration [7],[13].

All design assumptions, thermal limits, and correction factors presented in Table 4 are directly adopted from applicable international standards, primarily the IEC series (such as IEC 60364-5-52 and IEC 60364-5-54) and recognized industrial guidelines for cable sizing calculations as shown in Table 4.

Table 4. Design assumptions and correction factors based on IEC references [13].

Parameter	Value
Maximum outdoor ambient temperature	40 °C
Maximum conductor temperature for XLPE insulation	90 °C
Maximum conductor temperature for PVC insulation	70 °C
Maximum conductor temperature under short-circuit condition	250 °C
Motor starting power factor	0.25
Maximum DOL starting current	650% of full-load current
Feeder safety factor	K2 = 1.15
Motor safety factor	K2 = 1.25
Aboveground temperature correction factor	K3 = 0.91
Aboveground group derating factor	K1 = 0.79
Soil resistivity factor	K4 = 1.00
Short-Circuit Factor (k) XLPE	143 A.s ^{1/2} /mm ²

The design parameters presented in Table 4 represent the operating conditions used as the basis for cable-sizing calculations in this project. The maximum ambient temperature of 40°C was selected to represent outdoor operating conditions commonly encountered in oil and gas production facilities located in tropical regions. Elevated ambient temperatures reduce the cable's ability to dissipate heat and consequently decrease its effective ampacity [4],[6]. In addition to ambient temperature, cable grouping arrangements may create thermal interaction between adjacent cables. Therefore, a grouping factor of 0.79 and a temperature correction factor of 0.91 were applied to ensure that the actual current-carrying capability of the selected cables remains within acceptable operating limits [11],[13].

Furthermore, the use of safety factors for feeder and motor circuits provides an additional design margin against loading variations, field uncertainties, and future increases in power demand. This

approach contributes to improved reliability of the electrical distribution system during long-term operation. Then, in Table 4, the value $k = 143 \text{ A.s}^{1/2} / \text{mm}^2$ represents the thermal withstand constant for XLPE-insulated copper material, as defined by the standard. This value indicates that for every 1 mm^2 of conductor cross-section, the material can withstand a short-circuit current of 143 A for 1 seconds (with a maximum fault duration < 5 seconds) without exceeding the insulation temperature limit of 250°C .

3.3 Full Load Current of AC dan DC System

Full-load current calculation represents the initial stage of the cable-sizing process because it determines the minimum current that must be continuously carried by the conductor under normal operating conditions. This value serves as the basis for ampacity verification, voltage-drop analysis, and short-circuit withstand assessment. Therefore, accurate estimation of full-load current has a direct influence on the final conductor selection [11],[13].

3 phase AC system:

$$I_m = \frac{P \times 1000}{\sqrt{3} \times V_{L-L} \times pf \times Eff} \quad (1)$$

1 phase AC system:

$$I_m = \frac{P \times 1000}{V_{L-N} \times pf \times Eff} \quad (2)$$

DC system:

$$I_m = \frac{P \times 1000}{V_{dc}} \quad (3)$$

Overload current (I_d):

$$I_d = I_m \times K_2 \quad (4)$$

The application of a safety factor in the design current calculation provides an engineering margin during conductor selection. By incorporating this factor, the selected cable is capable of accommodating not only normal operating conditions but also load variations that may occur during the service life of the facility. This approach reduces the possibility of conductor operation near its thermal limit and contributes to improved system reliability [1],[13].

Where:

I_m	= Full load current of load (A)
I_d	= Over load current (A)
P	= Rating capacity (kW)
V_{L-L}	= Line to line voltage (V)
V_{L-N}	= Line to neutral voltage (V)
V_{dc}	= DC Voltage (V)
Pf	= Power Factor
Eff	= Efficiency (%)

3.4 Cable Ampacity

Cable ampacity is the maximum capacity of a cable to conduct electrical current continuously without exceeding the permissible temperature limit [4]-[6],[11]. In this calculation, the cable ampacity value from the manufacturer's catalog is corrected using an installation correction factor. Based on IEC 60364-5-52, the current-carrying capacity (KHA) of the cable. Cable sizing calculations are based on the Sumi Indo cable catalog, which specifies a maximum conductor temperature of 90°C for XLPE insulation and 70°C for PVC insulation. The cable KHA is calculated using the formula in Equation (5).

$$I_z \times K_1 \times K_3 \times K_4 \geq I_m \times K_2 \quad (5)$$

Where:

I_z	= Current-carrying Capacity of Cable (A)
I_m	= Full load current of load (A)
K_1	= Group Deracting Factor, Refer to IEC 60364-5-52
K_2	= Safety Factor
K_3	= Temperature Derating Factor
K_4	= Soil Resistivity Derating Factor

Equation (5) indicates that cable sizing cannot be performed solely on the basis of catalog ampacity values. The actual current-carrying capability of a conductor must be reassessed after applying correction factors that reflect field installation conditions. In this project, the combined effects of temperature and grouping correction factors reduced the effective ampacity of the selected cables and therefore influenced the final conductor size selection. These findings demonstrate that the application of derating factors is an essential part of cable design because neglecting installation correction factors may result in conductor sizes that are inadequate for actual operating conditions [4]-[6],[13].

3.5 Voltage Drop in Steady State and Motor Starting Conditions

Voltage drop is one of the primary indicators of electrical distribution system performance. Excessive voltage reduction may decrease equipment efficiency, increase power losses, and adversely affect motor performance. Consequently, cable selection should not be based solely on ampacity requirements but must also comply with allowable voltage-drop limits specified in the design criteria [1],[2].

Steady state conditions occur when the system is stable. The voltage drop and maximum allowable cable length can be seen in the following equation. Voltage drop when the motor starts is when the system voltage drops due to the event of a newly started motor entering the system [1],[2],[7],[13]. In this study, the analysis of motor starting considers two starting methods: Direct-On-Line (DOL) and Variable Speed Drive (VSD).

3.5.1 Steady State

The equations for three-phase, single-phase alternating current (AC) and direct current (DC) systems are stated as follows:

3 Phase AC system:

$$V_d = \frac{\sqrt{3} \times I_m \times (R \cos \varphi + X \sin \varphi) \times L}{1000 \times n} \quad (6)$$

$$V_d = \frac{V_d}{V_n} \times 100\% \quad (7)$$

$$L_{\max} = \frac{V_{dn} \times V_n \times 1000 \times n}{\sqrt{3} \times I_m \times (R \cos \varphi + X \sin \varphi) \times 100\%} \quad (8)$$

1 Phase AC system:

$$V_d = \frac{2 \times I_m \times (R \cos \varphi + X \sin \varphi) \times L}{1000 \times n} \quad (9)$$

$$V_d = \frac{V_d}{V_n} \times 100\% \quad (10)$$

$$L_{\max} = \frac{V_{dn} \times V_n \times 1000 \times n}{\sqrt{3} \times I_m \times (R \cos \varphi + X \sin \varphi) \times 100\%} \quad (11)$$

DC system:

$$V_d = \frac{2 \times I_m \times R \times L}{1000 \times n} \quad (12)$$

$$V_d = \frac{V_d}{V_n} \times 100\% \quad (13)$$

$$L_{\max} = \frac{V_{dn} \times V_n \times 1000 \times n}{2 \times I_m \times (R \cos \varphi + X \sin \varphi) \times 100\%} \quad (14)$$

The maximum cable length equations provide insight into the relationship between cable length, conductor impedance, and load current with respect to voltage-drop performance. This assessment is particularly important in industrial facilities where electrical equipment and process units may be located relatively far from the main distribution panel. As a result, conductor sizing can be optimized without compromising voltage quality at the load terminals [2],[13].

Where:

- V_n = Nominal system voltage (V)
- V_d = Voltage drop (V)
- V_{dn} = Percentage voltage drop (%)
- I_m = Full load current (A)
- $\cos \phi$ = Power factor
- R = Cable resistance (Ω/km)
- X = Cable reactance (Ω/km)
- L = Cable length (m)
- $L_{\max}$ = Maximum cable length (m)
- N = Number of parallel cables per phase

3.5.2 Motor Starting

The permissible starting voltage drop of the motor on the motor cable can be seen in the following equation.

$$V_{dst} = \frac{\sqrt{3} \times I_{st} \times (R \cos \phi + X \sin \phi) \times L}{1000 \times n} \quad (15)$$

$$V_{dnst} = \frac{V_{dst}}{V_n} \times 100\% \quad (16)$$

$$V_{dst} = \frac{V_{dnst} \times V_n \times 1000 \times 1000 \times n}{\sqrt{3} \times I_{st} \times (R \cos \phi + X \sin \phi) \times 100\%} \quad (17)$$

Motor-starting conditions generally produce the highest voltage-drop values encountered during normal system operation. During Direct-On-Line (DOL) starting, motor current may reach 5 - 7x times the rated current (I_{FLC}) for a duration of 5 - 10 seconds, causing temporary voltage reduction in the electrical network. Conversely, when a Variable Speed Drive (VSD) is utilized, the starting current is controlled and limited to approximately 1.0 - 1.5 x I_{FLC} , significantly mitigating starting voltage drop. Therefore, motor starting voltage drop evaluation is required to ensure that sufficient voltage remains available at the motor terminals to provide the necessary accelerating torque [7],[13].

Where:

- V_n = Nominal system voltage (V)
- V_{dst} = Motor starting voltage drop across the motor cable (V)
- V_{dnst} = Allowable voltage drop across the cable during motor starting (%)
- I_{st} = Motor starting current (A)
- $\cos \phi$ = Power factor
- R = Cable resistance (Ω/km)
- X = Cable reactance (Ω/km)
- L = Cable length (m)
- $L_{\max}$ = Maximum cable length (m)
- N = Number of parallel cables per phase

3.6 Short Circuit Withstand Capability of Cable

In determining cable size, the cable's ability to withstand short-circuit currents needs to be verified so that the conductor can withstand the fault current without exceeding the permissible temperature limit [3, 8, 14]. The minimum cross-sectional area of the conductor is determined based on the short-circuit current, fault duration, and conductor material constant according to IEC 60364-4-43 section 434.3.2 using the Equation (18).

$$S = \frac{I_{sc} \sqrt{t}}{k} \quad (18)$$

In addition to satisfying ampacity and voltage-drop requirements, conductors must also withstand the thermal energy generated during short-circuit conditions. Although fault durations are generally short, the magnitude of short-circuit current may produce significant temperature rise within the conductor. Consequently, short-circuit withstand verification is an essential component of cable-sizing analysis to ensure electrical safety and equipment reliability [3],[14].

Where:

- S = Nominal cross-sectional area of the conductor (mm²)
 I_{sc} = Short-circuit current value
 t = Time duration (s)
 k = Constant factor (for copper conductor with XLPE insulation = 143 A.s^{1/2}/mm²)

3.7 Representative Case study

To demonstrate the step-by-step mathematical formulation and the analytical approach applied within the calculation framework, a representative calculation example is presented below for the Water Injection Pump C cable route, which utilizes a VSD starting method (0.4 kV).

1. Equipment Data

Cable Route	= 0,4 Switchgear MCC to Water Injection Pump C
Length	= 150 meter (PSP-LVMCC-001 ke P-304C)
Rating	= 18,5 kW
Power Factor	= 0.78
Efficiency	= 0.91
Voltage	= 400 V
Cable Selected	= 4C x 35 mm ² (Ampacity, $I_c = 126$ A, R = 0.627 Ω /km, X= 0.0853 Ω /km)
Temperature Corr. Factor	= 0.91
Group Derating Factor	= 0.79
Soil Resistivity Factor	= 1.0

2. Continous Current Carrying Capacity (Overload Protection)

$$I_m = \frac{18,5 \times 1000}{\sqrt{3} \times 0,78 \times 0,91}$$

$$I_m = I_m \times K2 = 37,26A \times 1,25 = 47,03 A$$

$$I_z \times K1 \times K3 \times K4 = 126A \times 0,79 \times 0,91 \times 1,0 = 90,68 A$$

Because $I_z \times K1 \times K3 \times K4 \geq I_m \times K2$, a single run of 4C $\times$ 35 mm² cable is acceptable for the motor cable route from the 0.4 kV MCC switchgear to Water Injection Pump C.

3. Voltage Drop at Steady State

$$V_d = \frac{\sqrt{3} \times 37,62 \times (0,627 + 0,085 \times 0,6) \times 150}{1000 \times 1} = 5,30 V$$

$$V_{dn} = \frac{8,60}{400} \times 100\% = 2,15\%$$

Therefore, if $V_{dn} \leq 5\%$, 4C $\times$ 35 mm² cable with a single pull is acceptable for the motor cable route from the 0.4 kV Switchgear MCC to the Water Injection Pump C. VSD starts the motor by gradually increasing voltage and frequency, which keeps the starting current low around 100 – 150 of full-load current. Because this prevents large voltage drops during startup, starting voltage drop is not a major issue for VSD motors. Instead, the analysis focuses on the running voltage drop during normal operation.

4. RESULT AND DISCUSSION

The analysis was carried out for 16 main cable routes in the SP Puspa Asri area. All routes use a 400V system and 0.6/1 kV cable rating. The load types include generator feeders, distribution panels, welding receptacles, and several pump motors. The calculation results show that all cables comply with ampacity, voltage drop, and thermal withstand requirements. The main results are summarized in Table 5.

Table 5. Summary of cable sizing and voltage drop calculation results.

No.	Cable tag	Load	Cable Data		Corrected Iz (A)	Id (A)	Steady Vd (%)	Starting Vd (%)	Status
			Cable size (mm ²)	Length (m)					
1	GEG-001-P	Gas Engine Generator to LV MCC	2 runs 4C+E 95	113	342.20	338.76	1.69	N/A	Accepted
2	DEG-001-P	Diesel Engine Generator to LV MCC	2 runs 4C+E 95	113	342.20	338.76	1.69	N/A	Accepted
3	LDB-001-P	LV MCC to Lighting/ Small Power DB	4C+E 25	40	72.61	57.05	0.95	N/A	Accepted
4	CIA-001-P	Air Compressor Package	4C+E 16	110	57.51	43.62	1.77	4.96	Accepted
5	P-302-P	Test Pump A	3C+E 4	135	24.44	8.72	1.67	4.28	Accepted
6	P-303-P	Test Pump B	3C+E 4	133	24.44	8.72	1.65	4.22	Accepted
7	P-304-A-P	Water Injection Pump A	3C+E 10	138	43.13	31.99	2.54	6.79	Accepted
8	P-304-B-P	Water Injection Pump B	3C+E 10	145	43.13	31.99	2.66	7.13	Accepted
9	P-502-P	Jockey Pump	3C+E 4	160	24.44	6.40	1.45	3.72	Accepted
10	P-301-P	Booster Oil Loading Pump	3C+E 6	140	30.91	21.81	2.92	7.58	Accepted
11	WR-001-P	Welding Receptacle #1	4C+E 10	190	43.13	26.74	4.04	N/A	Accepted
12	WR-002-P	Welding Receptacle #2	4C+E 10	140	43.13	26.74	2.97	N/A	Accepted
13	P-306-P	Test Pump C	3C+E 4	150	24.44	11.63	2.48	6.35	Accepted
14	P-304-C-P	Water Injection Pump C	4C+E 35	150	90.58	47.03	1.33	3.95	Accepted
15	P-305-A-P	KO Drum A	3C+E 4	250	24.44	4.36	1.55	3.97	Accepted
16	P-305-B-P	KO Drum B	3C+E 4	250	24.44	4.36	1.55	3.97	Accepted

The cable sizing and voltage drop calculation results for all 16 evaluated circuits are summarized in Table 5. The selected conductor sizes range from 3C + E 4 mm² for small auxiliary drives up to 4C + E 95 mm² (configured in two parallel runs) for the high-capacity generator feeders. Overall, the results demonstrate that all evaluated routes satisfy the project design criteria regarding corrected ampacity ($I_z \geq I_d$), steady-state voltage drop $\leq 5\%$, starting voltage drop $\leq 15\%$ and short-circuit thermal withstand capability.

A detailed comparative analysis of the results reveals that cable sizing and voltage drop in this facility are heavily governed by the interaction between load current, routing distance, and motor-starting methods rather than load magnitude alone. The highest steady-state voltage drop across the entire station is observed on *Welding Receptacle #1 (WR-001-P)* at 4.04%, which approaches the 5% allowable ceiling. In contrast, *Welding Receptacle #2 (WR-002-P)* records a significantly lower drop of 2.97%, despite both circuits sharing identical electrical parameters 4C + E 10 mm² cable, $I_d = 26,74$ A, and $I_z = 43,13$ A. As detailed in Table 5, the primary technical driver for this 1.07% difference is the extended routing distance:

WR-001-P spans 190 m, whereas WR-002-P spans 140 m. The additional 50 m of cable increases the total series conductor impedance, which, when coupled with the low inductive power factor of welding equipment, drives the steady-state voltage drop higher.

Conversely, *Water Injection Pump C (P-304-C-P)* the largest continuous motor load in the project (18,5 kW, $I_d = 47,03$ A after applying a 1.25 safety factor) achieves a remarkably low steady-state voltage drop of 1.33% and a starting voltage drop of 3.95% over a 150 m route. The selected cable 4C + E 35 mm² yields an effective derated capacity of 90.58 A (accounting for temperature and grouping correction factors), providing a robust thermal margin. Furthermore, the integration of a Variable Speed Drive (VSD) effectively eliminates massive transient inrush currents, keeping starting voltage dips well controlled over long distances.

For Direct-On-Line (DOL) starting motor loads, transient starting voltage drops are noticeably higher due to unmitigated inrush currents ($5 - 7 I_{FLC}$). *Booster Oil Loading Pump (P-301-P)* (140 m, 3C + E 6 mm²) and *Water Injection Pump B (P-304-B-P)* (145 m, 3C + E 10 mm²) record the highest starting drops at 7.58% and 7.13%, respectively. Although well within the 15% threshold, these transient values highlight the trade-off between simpler DOL starting and line voltage stability, justifying why VSDs are reserved for critical continuous process drives like P-304-C-P.

Incorporating temperature and grouping derating factors proved essential during conductor selection. Relying solely on catalog base ampacities would have resulted in undersized conductors under actual field installation conditions. The operational margins provided by the corrected ampacities ensure lower conductor operating temperatures, reducing insulation thermal ageing and extending overall cable service life [5],[8]. These findings align with previous literature emphasizing that power cable selection must simultaneously satisfy thermal ampacity, installation derating, and voltage drop limits to guarantee operational reliability [1],[2],[7].

5. CONCLUSION

This study concludes that the power cable sizing for the Upgrading Stasiun Pengumpul Puspa Asri 2 Project satisfies the technical criteria for current-carrying capacity, voltage drop, and short-circuit thermal withstand capability. The evaluation of 16 cable routes shows that all selected cables have corrected current-carrying capacities greater than the design currents and voltage drops below the specified limits. The analysis further indicates that temperature correction factors, grouping factors, and voltage-drop limitations have a significant influence on the final conductor selection. Therefore, cable sizing in industrial facilities should not be based solely on nominal load current but must also consider installation conditions and applicable technical constraints to ensure reliable, safe, and compliant long-term operation. The selected cable design is technically feasible to support facility operation. The results also demonstrate that the application of IEC-based derating factors and voltage-drop criteria provides an effective engineering basis for cable selection in oil and gas production facilities.

This study successfully evaluated the low-voltage power cable sizing for 16 critical circuits in the Puspa Asri Phase 2 Station upgrading project based on IEC 60364 and IEC 60287, SNI standards etc. The key finding demonstrates that all evaluated cable routes comply with full-load current demands, continuous ampacity limits, short-circuit thermal withstand criteria, and voltage drop ($\leq 5\%$ steady-state and $\leq 15\%$ starting). The analysis reveals that cable performance is heavily governed by routing distance and motor-starting strategy rather than load magnitude alone; notably, the longest auxiliary feeder (WR-001-P, 190 m) records the highest steady-state voltage drop at 4.04%, whereas the largest process drive (P-304-C-P, 18.5 kW) achieves a low 1.33% running drop due to Variable Speed Drive (VSD) integration and proper conductor sizing (35 mm²).

Practically, incorporating temperature and grouping derating factors provides a crucial safety margin that prevents thermal overheating, reduces insulation ageing, and ensures long-term power system reliability in harsh brownfield environments. Furthermore, this study demonstrates that a structured deterministic analytical model serves as an accurate, accessible alternative for verifying brownfield electrical distribution upgrades without sole reliance on complex simulation software.

Despite these contributions, a primary limitation of this work is its dependence on static project design data and vendor catalog specifications rather than dynamic field-measured operating parameters. To address these limitations, future research should integrate real-time field thermal measurements, evaluate harmonic distortion effects introduced by VSD drives on cable lifetime, and extend the analytical scope to include dynamic short-circuit protection coordination across the distribution network.

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AUTHOR CONTRIBUTIONS

PW: Conceptualization, Formal analysis, Methodology, Investigation, Writing (original draft). LW: Supervision, Validation, Writing (review & editing). All authors have read and approved the final manuscript.

CONFLICT OF INTEREST

The authors declared that there is no conflict of interest of this work.

ETHICAL CLEARANCE STATEMENT

This study did not involve human participants, personal data, or animals; ethical clearance was not required.

DECLARATION OF AI TOOL USAGE

The authors declared that no generative AI or AI-assisted technologies were used in the preparation of this manuscript.

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