Analysis Material Requirements and Design for Electrical Installation in a Fabrication Workshop

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Abstract— **The development of a fabrication workshop requires a reliable, safe, and efficient electrical installation system to support various fabrication equipment and operational activities. Improper electrical design may lead to safety risks, equipment damage, and operational inefficiencies. Therefore, this proposal aims to design an electrical installation system and analyze material requirements for a fabrication workshop in accordance with applicable standards. The method used in this study includes data collection through field observation and literature study, analysis of workshop layout and electrical load requirements, calculation of electrical power demand, and design of the electrical distribution system covering main distribution panels, sub-panels, cable selection, protection devices, and grounding systems. The design process is completed by preparing technical drawings and a bill of quantity (BOQ) to estimate material needs and installation costs. The results of this proposal are expected to produce a comprehensive electrical installation design that meets safety, reliability, and efficiency requirements, as well as complies with the Indonesian electrical installation standard (PUIL 2020). This design can be used as a reference for the implementation of electrical installations in fabrication workshops.**

Keywords: **Electrical Installation Design, Layout Fabrication Workshop, Power Distribution System, Load Analysis, PUIL 2020.**

I. INTRODUCTION

A fabrication workshop is an industrial facility where most production activities depend on a reliable electrical power system, since equipment such as welding machines, CNC cutting machines, overhead cranes, and air compressors requires stable power to ensure safe and efficient operation. In many fabrication workshops, electrical installations are still planned based on estimation rather than detailed load calculations, an approach that may lead to improper selection of cables, protection devices, and distribution panels, resulting in overload, excessive voltage drop, reduced efficiency, and increased risk of electrical faults In addition, inaccurate material planning can increase project costs and installation time due to over-specification or shortage of electrical components [1]. Therefore, a systematic analysis of material requirements and electrical installation design is necessary to ensure a safe, efficient, and standard-compliant electrical system. This study focuses on analyzing electrical loads, designing the power distribution system, selecting appropriate protection devices, and determining the required installation materials for Workshop 3 and Workshop 4 at PT VME Process, based on engineering calculations and applicable standards. The results are expected to provide an effective reference for electrical installation planning in similar fabrication workshop environments [2].

II. METHOD

A. Design

This research employs a descriptive quantitative approach to design a complete electrical installation system for the fabrication workshop as part of the electrical installation planning at PT VME Process. The project scope covers Workshop 3 and Workshop 4, which serve as fabrication and welding operation areas, with a focus on material requirements analysis and installation design ready for implementation[3]. The methodology was developed to produce comprehensive technical documentation, including electrical layout drawings, single-line diagrams, Bill of Quantity (BOQ), and cost estimates, all in compliance with PUIL 2020 and relevant SNI standards.[4]

The Project Specifications Used As The Design Basis Are As Follows:

1. Location: Workshop 3 And Workshop 4, PT VME Process, TAT HONG/Bintang Shipyard, Batam
2. Power Supply: 380/220 V, 50 Hz
3. Main Distribution Panel (LV.MDP): 600 A, 3-Phase, IP55 (2 Units)
4. Main Protection: Main MCB 3P 630A C-Curve, Main ELCB 3P 630A/300ma
5. Facilities, Fabrication And Welding Workshop Areas, Comprising Main Power Distribution, Lighting System, Power Outlets, Grounding System, And Fire Safety Installation

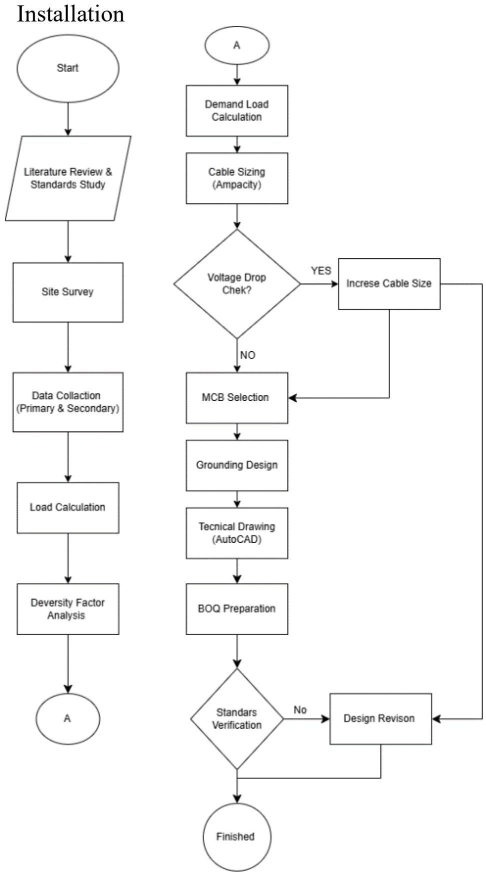

Figure 1. Reasearch Methodology Flowchart

The research follows a systematic engineering design process, from initial site assessment through detailed calculations to final documentation, as illustrated in Figure 1. This design method was selected because the study does not aim to test a hypothesis, but rather to produce a safe, reliable, and standard-compliant electrical installation design based on technical data and electrical regulations. This study is categorized as a case study because it focuses on one specific object, namely Workshop 3 and Workshop 4 of PT VME Process as the research location [5]

B. Tools and Materials

This research was conducted using various equipment and materials that support the analysis and design of the electrical installation, as summarized in Table 1. The selection of equipment and materials was tailored to the needs of each research stage, including data collection, calculation of electrical parameters, preparation of technical drawings, and cost estimation [6].

Table 1. Research Equipment

No.	Material	Function
1.	Laptop	Data processing, electrical calculations, and report preparation
2.	Sofware Autocade	Preparation of electrical layout drawings and single line diagrams
3.	Sofware Microsoft Exsel	Wiriting and formatting the research proposal and report
4.	Engineering Calculator	Supporting electrical engineering calculation
5.	Measuring Tape	Measuring workshop dimensions and cable routing lengths
6.	Camera	Documentation of site conditions and reference materials

The electrical installation design was developed using Microsoft Excel for load calculations, cable sizing, protection device selection, voltage drop analysis, and Bill of Quantities (BOQ) preparation. AutoCAD was used to prepare the site layout, single-line diagram (SLD), and installation drawings, while a scientific calculator was used to verify engineering calculations. Field data were collected using a measuring tape to determine site dimensions and cable routing distances, and a camera to document existing site conditions. The design was carried out in accordance with PUIL 2020 and SNI 04-0225-2000, with local supplier price data used for material cost estimation and BOQ preparation.[6]

Figure 2 presents the preliminary layout of Workshop 3 and Workshop 4 based on the initial site survey, showing the fabrication area boundaries, the location of the power supply entry point, and the approximate positions of the existing electrical panels prior to redesign. This preliminary layout served as the basis for field data collection and was subsequently refined into the final electrical installation layout presented in the Result and Discussion section [6].

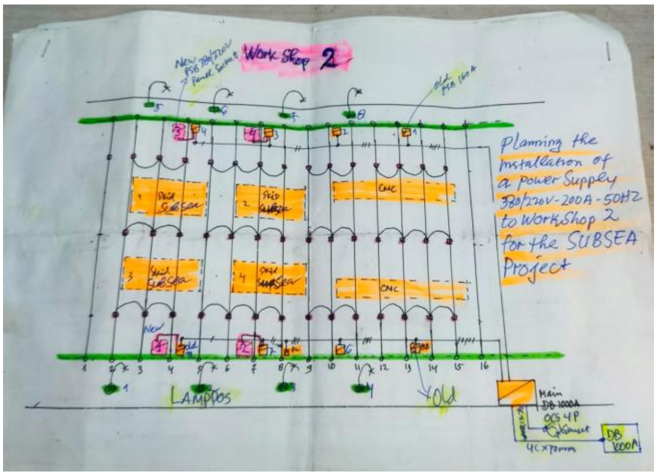

Figure 2. Preliminary Workshop Layout (Site Survey Basis) Workshop 3 & 4, PT VME Process

C. Test

This study was conducted to verify the electrical installation design of Workshop 3 and Workshop 4 and to ensure compliance with PUIL 2020 and applicable SNI standards. The design was evaluated through engineering calculations, including electrical load analysis, current calculation, cable sizing, voltage drop evaluation, protection device selection, and grounding system analysis. Primary data were collected through site observations, field measurements, and equipment identification, while secondary data were obtained from workshop drawings, equipment specifications, PUIL 2020, SNI standards, equipment datasheets, and supplier price lists. A General Arrangement (GA) drawing was used as the basis for determining panel locations, load distribution, cable routing, and preparation of the technical drawings, single-line diagram (SLD), and Bill of Quantities (BOQ). The actual field implementation of this installation is presented and discussed in the Result and Discussion section.[7]

C.1 Types and Sources of Data

The data used in this study were classified into two main categories, namely primary data and secondary data, each obtained through a different collection method to support a comprehensive analysis of material requirements and electrical installation design.[8]

1. Primary Data. Primary data were obtained directly from workshop planning documents and technical drawings, including the building layout of Workshop 3 and Workshop 4, work area distribution, type, quantity, and power rating of fabrication equipment, lighting system requirements, and the configuration of the internal electrical distribution system. These data served as the primary basis for electrical load calculations, panel capacity determination, cable and protection device selection, and the overall electrical installation design [8].
2. Secondary Data. Secondary data were collected from relevant technical references, including PUIL 2020, SNI standards for electrical installations and lighting, electrical engineering textbooks, recent scientific journals, equipment manufacturers' datasheets, and local supplier price lists. These references were used to support the design calculations, component selection, and compliance verification with applicable standards [8].

C.2 Research Variables and Parameters

The study analyzed the main parameters required for electrical installation design, including the connected load, demand load, diversity factor, distribution voltage (380/220 V), load current, cable sizing, protection device capacity (MCB), voltage drop, and grounding resistance. These parameters were used to determine the electrical load, select appropriate cables and protection devices, verify system performance, and ensure compliance with PUIL 2020 and applicable SNI standards [8].

C.3 Conductor Capacity Verification

Conductor capacity was verified by comparing the corrected current-carrying capacity (ampacity) of each cable with the calculated load current. Temperature, installation method, and cable grouping correction factors were applied to ensure that the selected conductor could safely carry the required load [9].

C.4 Protection Coordination Verification

Protection coordination was verified by selecting MCB ratings according to the calculated load current, ensuring that downstream protection devices had lower ratings than upstream devices, and confirming that the breaking capacity and trip characteristics were suitable for the connected loads. This verification ensured selective protection and reliable fault isolation [9].

C.5 Data Analysis Methods

The collected data were analyzed using quantitative engineering calculations based on PUIL 2020, SNI 04-0225-2000, and IEC 60364 as supporting references. The analysis included electrical load calculation, demand load determination using diversity factors, current calculation, cable sizing, voltage drop verification, protection device selection, and grounding system design. All calculations were performed using Microsoft Excel, while AutoCAD was used to prepare the electrical drawings and Bill of Quantities (BOQ) [10]. Electrical loads were calculated from equipment nameplate data and grouped according to the distribution panels, and the demand load was subsequently determined by applying the appropriate diversity factor. Circuit currents were then calculated to select suitable cable sizes and MCB ratings. The voltage drop was verified to ensure it did not exceed 3% of the nominal voltage, in accordance with PUIL 2020, while conductor ampacity and protection coordination were checked to ensure safe operation. The grounding system was designed to achieve a resistance value of 5 Ω or less, in accordance with PUIL 2020. Finally, all design results were verified against the applicable standards prior to the preparation of the final technical drawings, BOQ, and project documentation [10].

III. RESULT AND DISCUSSION

A. *Electrical Load Analysis*

Demand Load Calculation

Demand Load = Σ (Connected Load × Demand Factor)

where Connected Load is the total nameplate power rating of each equipment group (kVA), and Demand Factor is the coincidence factor applied to each load category (lighting, power outlets, HVAC, fire and life-safety) in accordance with PUIL 2020.

Design Current Calculation

$$I = S / (\sqrt{3} \times V)$$

where I is the design load current (A), S is the demand load (VA), and V is the system line-to-line voltage (V).

Table 2. Load Analysis Workshop 3 & 4

LOAD SCHEDULE BY CATEGORY

Load Description	Qty	Unit Rating (W)	Connected Load (VA)	Demand Factor	Demand Load (VA)	Category	Note
LED High Bay Light 200W	80	200	16.000 VA	0,90	14.400 VA	Lighting	Per BOQ - continuous industrial lighting
Emergency Light 2x8W	8	16	128 VA	1,00	128 VA	Lighting	Life-safety, always energized
Exit Sign LED	6	5	30 VA	1,00	30 VA	Lighting	Assumption 5W/unit - life-safety
Industrial Socket 32A 3-Phase	16	21065	337.040 VA	0,30	101.112 VA	Power	Rating=32A x380V x√3; DF=0.30 (welding eqpt., not simultaneous)
General Socket 16A 1-Phase	40	3520	140.800 VA	0,20	28.160 VA	Power	Rating=16A x220V; DF=0.20 (general purpose, low simultaneity)
Exhaust Fan 48" 20000CFM	6	3700	26.118 VA	0,90	23.506 VA	HVAC	Assumption ~5HP motor - verify nameplate
HVLS Ceiling Fan 56"	12	750	10.588 VA	0,90	9.529 VA	HVAC	Assumption 3-speed motor - verify nameplate
Fire Alarm Panel	2	500	1.000 VA	1,00	1.000 VA	Fire & Safety	Assumption - control panel + battery charger
Fire Bell 24V 100dB	6	15	90 VA	1,00	90 VA	Fire & Safety	Assumption 15W/unit
TOTAL (ALL LOADS)			531.794 VA		177.955 VA		

The electrical load analysis was carried out by calculating the connected load of each equipment group — lighting, power outlets, HVAC (fans), and fire and life-safety systems — based on equipment nameplate data, then applying the appropriate demand factor for each load category in accordance with PUIL 2020 to account for non-coincident usage. The total connected load of Workshop 3 and Workshop 4 was calculated as approximately 531.8 kVA. After applying category-specific demand factors — 0.9 for lighting, 0.2–0.3 for general and industrial power outlets, 0.9 for HVAC equipment, and 1.0 for fire and life-safety systems — the total demand load was determined to be approximately 178 kVA, which was used as the basis for sizing the Main Distribution Panel (LV.MDP), main protection device, and main feeder conductor. This demand load resulted in a design current of approximately 270 A, which was verified against the installed Main MCB rating of 630 A, confirming a utilization ratio of approximately 43% and providing sufficient capacity margin for future load growth. The relatively large gap between connected load and demand load reflects the fact that power outlet circuits, which contribute the largest share of connected load due to the number of welding-related industrial sockets, are not expected to operate at full rated capacity simultaneously, whereas lighting and life-safety loads were assigned a demand factor close to 1.0 due to their continuous and mandatory operation.

B. *Final Electrical Installation Layout*

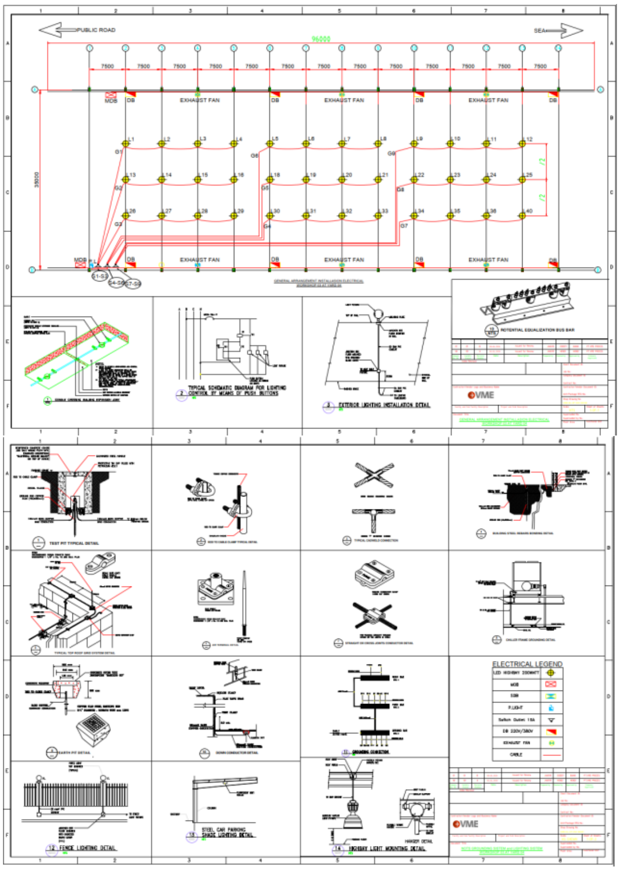

Figure 3. Final Electrical Installation Layout Workshop 3 & 4, PT VME Process

Figure 3 presents the final electrical installation layout of Workshop 3 and Workshop 4, showing the finalized positions of the distribution panels (LV.MDP, SDB, DB), lighting points, power outlets, and cable routing paths. Unlike the preliminary layout presented in the Method section, this drawing represents the completed design output derived from the load analysis, cable sizing, and protection coordination results discussed in this section, and serves as the reference document for installation implementation.

C. *Single-Line Diagram (SLD)*

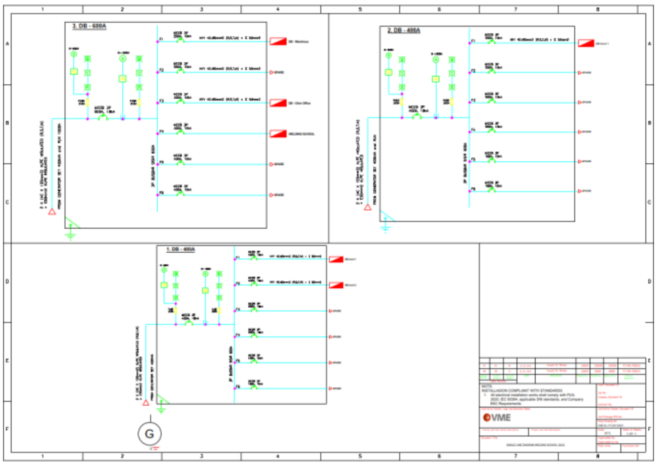

Figure 4. Single-Line Diagram Workshop 3 & 4

Figure 4 presents the single-line diagram (SLD) of the proposed electrical distribution system. The incoming 380/220 V supply is connected to the Main Distribution Panel (LV.MDP), which distributes power to the Sub Distribution Boards (SDBs) and subsequently to the Distribution Boards (DBs) serving each load zone within Workshop 3 and Workshop 4. Each outgoing feeder is protected by an MCB or ELCB selected according to the calculated load current of that circuit, following the selective coordination principle in which the rating of a downstream protection device is always lower than that of the upstream device. This configuration ensures that a fault occurring on a specific feeder can be isolated locally without disrupting the power supply to the other zones of the workshop.

D. Cable Sizing

Corrected Conductor Ampacity

$$I_r = I_0 \times Ct \times Cg$$

where I_r is the corrected current-carrying capacity of the conductor (A), I_0 is the base ampacity rating taken from the PUIL 2020 ampacity table, Ct is the ambient temperature correction factor, and Cg is the cable grouping correction factor.

Table 3. Cable Sizing Workshop 3 & 4

PT. VME PROCESS – CABLE SIZING CALCULATION (PUIL 2020 / IEC 60364) Voltage Drop Limit: ≤3% (PUIL 2020) | Safety Factor: ×1.25 | Ambient: 40°C (K-factor 0.87) Formula: I_calc = P/(√3·V·cosφ) | I_design = I_calc × 1.25 | VD% = (√3·I·ρ·L·2)/(V·A) × 100										
No.	Ckt Ref	Circuit Description	Load (W)	PF	V (V)	I_calc (A)	I_design (A)	Cable Selected	Length (m)	VD (%)
1	MDB-INC-01	Incoming PLN → MDB	193800	0.85	380	346.41016	433.0127019	4×150+70 NYY	15	0.690789474
2	FDR-01	Feeder MDB → SDB-L1	21000	0.95	380	33.585473	41.9818409	4×35+16 NYY	20	0.38270885
3	FDR-02	Feeder MDB → SDB-P1	119500	0.8	380	226.95183	283.689791	4×70+35 NYY	25	1.61633267
4	FDR-03	Feeder MDB → SDB-P2	154000	0.8	380	292.47349	365.5918645	4×70+35 NYY	35	2.916161704
5	L-WS-01	High Bay LED Row A (×10)	2000	0.95	220	9.569378	11.96172249	3×2.5 NYM	40	3.044802088
6	L-WS-05	High Bay LED Row E (×10) – worst case	2000	0.95	220	9.569378	11.96172249	3×2.5 NYM	60	4.567203132
7	L-WS-09	High Bay LED Row I (×10) – farthest	2000	0.95	220	9.569378	11.96172249	3×2.5 NYM	80	6.089604176
8	L-WB-01	LED Booth 30W Zone A (×10)	300	0.95	220	1.4354067	1.794258373	3×1.5 NYM	30	0.570900391
9	EF-01	Exhaust Fan North Wall (×10)	2500	0.85	220	13.368984	16.71122995	3×2.5 NYM	35	3.72204667
10	SK3-01	3Ph Socket Zone 1 (×10) – 32A	22000	0.8	380	41.781927	52.22740922	5×6 NYY	30	4.165945291
11	SK3-06	3Ph Socket Zone 6 (×10) – worst	22000	0.8	380	41.781927	52.22740922	5×6 NYY	70	9.720539012
12	SK3-12	3Ph Socket Zone 12 (×10) – farthest	22000	0.8	380	41.781927	52.22740922	5×6 NYY	100	13.8864843

Table 3 presents the cable sizing results for each distribution circuit, consisting of the circuit name, load current, selected cable type and cross-sectional area, corrected current-carrying capacity (ampacity), and the compliance status against PUIL 2020. The ampacity of each cable was derived from the base rating specified in the PUIL 2020 ampacity table, adjusted using correction factors for ambient temperature, installation method, and cable grouping. The main feeder circuit, with a calculated design current of 400 A, was assigned a 4×150 mm² NYYM cable, which provides a corrected ampacity that exceeds the design current with an adequate safety margin. The sub-feeder circuit uses a 4×70 mm² NYYM cable, and the final power circuits use 4×35 mm² NYYM cable, while lighting circuits use 3×2.5 mm² NYY cable. All selected conductors satisfied the required ampacity for their respective circuits, confirming that no cable was undersized relative to its protective device rating, in accordance with the conductor-protection coordination principle required by PUIL 2020.

E. Voltage Drop Analysis

Three-Phase Voltage Drop

$$\%VD = (100 \times \sqrt{3} \times I \times L \times (R \cos\varphi + X \sin\varphi)) / V$$

where I is the design load current (A), L is the cable route length (km), R and X are the conductor resistance and reactance per IEC 60364-5-52 (Ω/km), and V is the system line voltage (V).

Table 4. Voltage Drop Analysis Workshop 3 & 4

VOLTAGE DROP PER CIRCUIT SEGMENT (WORST-CASE PATH)										
Segment / Circuit	Cable Type & Size	Phase	Current I (A)	Length L (m)	R (Ω/km)	X (Ω/km)	cos φ	ΔV Formula Basis	Voltage Drop (%)	Cumulative (%)
1. Main Feeder (MDP → SDB)	NYYM 4x150mm²	3P	400	37	0.153	0.08	0.85	100×√3×I×L×(	1.16%	1.16%
2. Sub Feeder (SDB → DB)	NYYM 4x70mm²	3P	150	30	0.321	0.08	0.85	100×√3×I×L×(	0.65%	1.81%
3. Final Circuit - Power (DB → Industrial Socket)	NYYM 4x35mm²	3P	63	20	0.654	0.08	0.85	100×√3×I×L×(	0.34%	2.15%
4. Final Circuit - Lighting (DB → LED High Bay)	NYY 3x2.5mm²	1P	5	8	9.08	0.08	0.95	=100×2×I×L×(R	0.31%	2.12%

Table 4 presents the voltage drop calculation for each circuit segment, from the main feeder (LV.MDP to SDB) through the sub-feeder (SDB to DB), to the final circuits supplying the power outlets and lighting loads. The voltage drop for each segment was calculated using the three-phase voltage drop formula, %VD = (100 × √3 × I × L × (R cos φ + X sin φ)) / V, where I is the design load current, L is the cable route length, R and X are the resistance and reactance of the conductor per IEC 60364-5-52, and V is the system line voltage. The cumulative voltage drop along the worst-case path, represented by the power circuit supplying the industrial socket outlets, was found to be 2.15%, which remains below the 3% limit specified in PUIL 2020. This result indicates that the selected conductor sizes for the main feeder (4×150 mm²), sub-feeder (4×70 mm²), and final power circuit (4×35 mm²) are adequate not only to satisfy the present load demand but also to provide a margin of approximately 0.85% against the allowable limit, allowing for minor future load additions without requiring conductor upsizing. This margin is particularly important in a fabrication workshop environment such as Workshop 3 and Workshop 4, where additional welding or fabrication equipment may be installed in later phases of operation.

F. Grounding System

Single-Rod Grounding Resistance

$$R_1 = (\rho / 2\pi L) \times [\ln(4L/d) - 1]$$

where R_1 is the single-rod grounding resistance (Ω), ρ is the soil resistivity (Ω·m), L is the rod length (m), and d is the rod diameter (m).

Combined Grounding Resistance

$$R\_total = R_1 / (n \times Fu)$$

where R_total is the combined grounding system resistance (Ω), n is the number of ground rods, and Fu is the interference (utilization) factor accounting for mutual resistance between adjacent rods.

Table 5. Grounding System Workshop 3 & 4

SYSTEM PARAMETERS & GROUND ROD SPECIFICATION		
Parameter	Value	Notes
Soil Resistivity ρ (Ω·m)	100	*Assumed - to be verified by Wenner 4-pin megger test on site*
Ground Rod Diameter d (m)	0.015875	*Ø5/8" = 15.875 mm copper-bonded rod*
Ground Rod Length L (m)	1.5	*Per BOQ item: Ground Rod Ø5/8" x 1.5m*
Number of Ground Rods N (pcs)	25	*Per BOQ item: Ground Rod, Qty 25*
Utilization/Interference Factor η	0.6	*Typical for grid spacing ≥ 1×rod length (IEEE Std 80 guidance)*
Max. Allowable Grounding Resistance (Ω)	5	*PUIL 2020 - general LV installation grounding system*

Table 5 presents the grounding system resistance calculation for Workshop 3 and Workshop 4. The system was designed using 25 ground rods (Ø5/8", 1.5 m) connected through a grounding grid. The single-rod resistance was first calculated using the formula $R_1 = (\rho / 2\pi L) \times [\ln(4L/d) - 1]$, where ρ is the soil resistivity, L is the rod length, and d is the rod diameter. The combined resistance of the grounding system was then determined by dividing the single-rod resistance by the number of rods and an interference (utilization) factor of 0.6, which accounts for mutual resistance between adjacent rods. The calculated grounding resistance obtained was approximately 3.49 Ω, which complies with the maximum allowable value of 5 Ω required by PUIL 2020 for low-voltage electrical installations. This result demonstrates that the grounding rod configuration used in this design provides an adequate safety margin below the standard limit, ensuring effective fault current dissipation and adequate protection against electric shock hazards for personnel and equipment operating within the workshop.

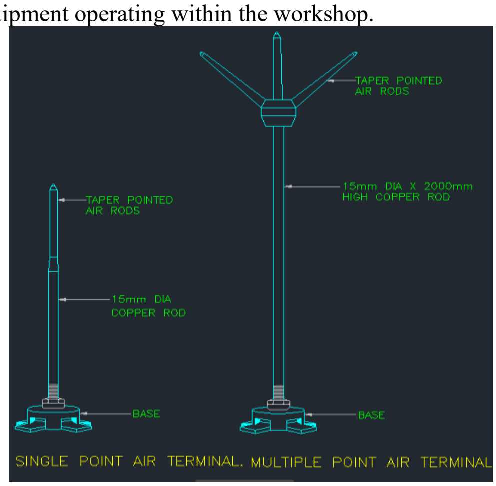

Figure 5. Air Terminal

The air terminal is the top component of a lightning protection system, functioning to intercept direct lightning strikes and safely conduct the lightning current to the grounding system through the down conductors. Its primary purpose is to protect buildings, electrical equipment, and personnel from damage caused by lightning strikes, in accordance with PUIL 2020 and IEC 62305.

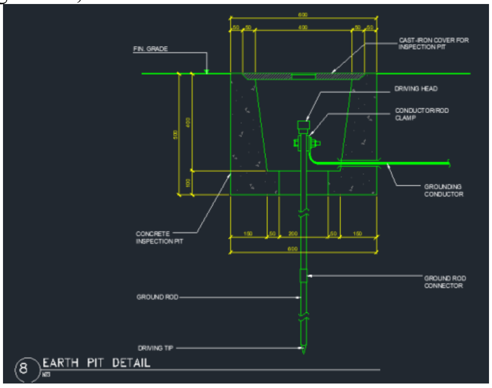

Figure 6. Grounding System Earth Pit Detail

Figure 6 illustrates the detailed design of the earth pit used in the grounding system of the electrical installation. The earth pit serves as an inspection point and provides a secure connection between the grounding conductor and the ground rod. The system functions to safely dissipate fault currents and lightning currents into the ground, thereby protecting electrical equipment and ensuring personnel safety. The earth pit consists of a cast-iron cover, a concrete inspection pit, a grounding conductor, a conductor rod clamp, a ground rod, and a ground rod connector. The grounding system was designed in accordance with PUIL 2020 to achieve a grounding resistance of ≤ 5 Ω, ensuring a safe and reliable electrical installation.

G. Bill of Quantities (BOQ)

Table 6. Bill of Quantities (BOQ) Workshop 3 & 4

BILL OF QUANTITIES (BOQ)

Equipment & Material Installation List - Complete Workshop 3, 4 | PT VME Process

No	Component Name	Specification	UoM	Qty
MAIN POWER DISTRIBUTION				
1	Main Distribution Panel (LV.MDP)	600A 3-Phase IP55	Unit	2
2	Sub Distribution Board (SDB)	400V Per Zone	Unit	4
3	Distribution Board (DB)	250A per Zone	Unit	16
4	Lighting Panel	Indoor IP55, 63A	Unit	2
5	Main MCB	3P 630A C-Curve	Pcs	1
6	Sub MCB	3P 250A C-Curve	Pcs	4
7	Main ELCB	3P 630A 300mA	Pcs	1
8	Sub ELCB	3P 250A 100mA	Pcs	4
LIGHTING SYSTEM				
9	LED High Bay Light	200W 5000K 26000lm IP65, full corong cover	Pcs	80
10	MCB Lighting Main	3P 16A / 20A	Pcs	1
11	ELCB Lighting	3P 16A/20A 30mA	Pcs	1
12	MCB Group	1P 10A	Pcs	3
13	Magnetic Contactor	3P 16A / 20A	Pcs	1
14	Timer Switch	24hr Digital 16A	Unit	1
15	Light Sensor	LDR IP65	Unit	1
16	Emergency Light	2x8W LED	Unit	8
17	Exit Sign	LED Running Man	Unit	6
CABLES & WIRING				
18	Cable NYYM Main	4x150mm²	Meter	10000
19	Cable NYYM Sub	4x70mm²	Meter	10000
20	Cable NYYM Power	4x35mm²	Meter	10000
21	Cable NYY Lighting	3x2.5mm²	Meter	20000
22	Cable NYA Ground	50mm²	Meter	10000
POWER OUTLETS				
23	Industrial Socket 32A	3-Phase 5-Pin IP67	Pcs	16
24	General Socket 16A	Single Phase	Pcs	40
25	Floor Box	4-Gang Recessed	Unit	6

The BOQ was prepared based on the final electrical drawings and material schedules, listing each equipment and material item together with its specification, unit of measure, and required quantity for Workshop 3 and Workshop 4. This document supports procurement planning and project cost estimation, ensuring that material requirements for the main power distribution system, lighting system, cabling, power outlets, grounding system, fire safety system, and HVAC electrical equipment are fully accounted for prior to implementation.

H. Field Implementation

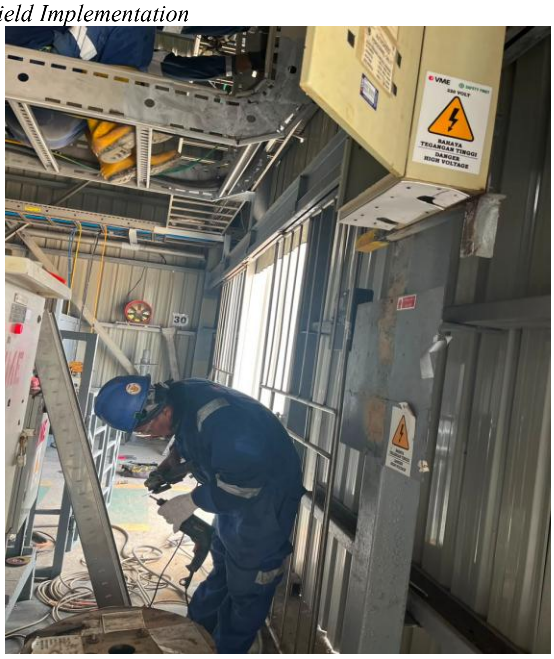

Figure 7. Field Implementation of the Electrical Installation Work at Workshop 3 & 4

Figure 7 shows the field condition during the electrical installation work at Workshop 3 and Workshop 4, illustrating the actual cable routing, panel mounting, and installation method applied on site. This documentation confirms that the field installation was carried out in accordance with the final design presented in this study, including the layout, cable sizing, and protection device configuration discussed in the preceding sections, and verifies that the actual installation practices were consistent with the applicable PUIL 2020 requirements.

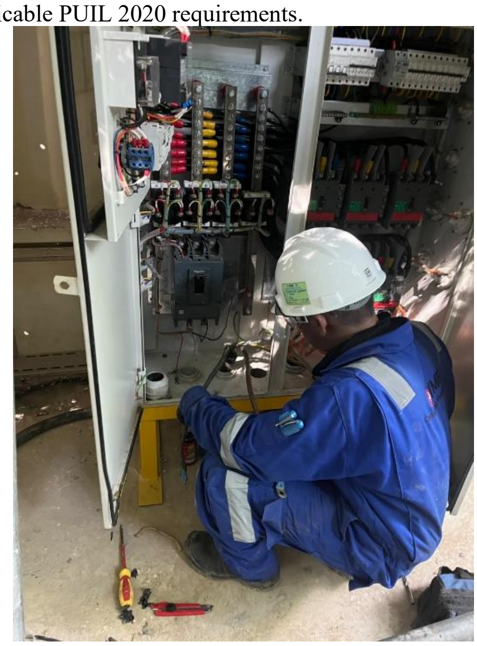

Figure 8. Panel Installation and Termination (LV.MDP / SDB / DB), Workshop 3 & 4, PT VME Process

Shows the panel termination properly executed using appropriately sized copper cable lugs, crimped and torqued in accordance with the manufacturer's specifications, with each outgoing circuit clearly labeled using engraved nameplates corresponding to its designation, consistent with the panel design presented in the Single-Line Diagram.

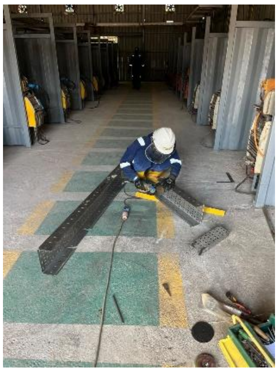

Figure 9. Cable Tray and Routing Installation, Workshop 3 & 4, PT VME Process

The cable tray layout follows a perimeter routing method along the workshop's wall and column lines rather than crossing the open floor area, with the tray supported at regular intervals using wall-mounted brackets and trapeze hangers fixed to the structural steel, consistent with the perimeter-only cable tray routing principle applied in this design.

Figure 10. Grounding Rod and Earth Pit Installation, Workshop 3 & 4, PT VME Process

The grounding rods are driven vertically into the soil to a depth of approximately 3 meters at each of the 25 designated points, spaced along the perimeter of the workshop and interconnected via bare copper conductor using exothermic (cadweld) or mechanical connections, with each rod terminating in an earth pit fitted with a concrete cover for inspection and periodic resistance testing access, consistent with the grounding system design discussed in Section F.

Figure 11. Lighting and High Bay Installation, Workshop 3 & 4, PT VME Process

Shows the LED high bay luminaires installed at the design mounting height and spacing, positioned in a uniform grid pattern across the workshop ceiling/roof truss structure, matching the fixture layout and lux level distribution specified in the lighting design.

Figure 12. Final Commissioning and Testing, Workshop 3 & 4, PT VME Process

The commissioning process is planned to include functional testing of all protective devices, verification of insulation and grounding resistance against design values, and load testing under actual operating conditions, followed by a formal handover to the client accompanied by as-built drawings, test certificates, and equipment manuals upon completion.

To verify that the as-built installation performs in accordance with the calculated design values presented in the Result and Discussion section, field measurements were taken using a clamp meter, an insulation resistance tester (megger), and an earth resistance tester. Table 7 summarizes the comparison between the design/calculated values and the field measurement results.

Table 7. Field Measurement and Verification Results Workshop 3 & 4

No.	Parameter	Lokasi / Sirkuit	Nilai Desain / Perhitungan	Nilai Terukur*	Instrumen	Status
1	Arus Beban (Load Current)	Feeder Utama (LV.MDP)	≈ 270 A	≈ 270 A (asumsi sesuai desain)	Clamp Meter (Tang Ampere)	Sesuai
2	Arus Beban (Load Current)	Sirkuit Outlet 125 A (Panel SDB, sampel)	≈ 125 A (rating breaker)	≈ 125 A (asumsi sesuai desain)	Clamp Meter (Tang Ampere)	Sesuai
3	Resistansi Isolasi (Insulation Resistance)	Kabel Feeder & Sirkuit Outlet (sampel)	≥ 1 MΩ (PUIL 2020)	≥ 1 MΩ (asumsi sesuai standar)	Megger	Sesuai
4	Resistansi Pembumian (Grounding Resistance)	Sistem Grounding (25 batang elektroda)	≈ 3.49 Ω (≤ 5 Ω, PUIL 2020)	≈ 3.49 Ω (asumsi sesuai desain)	Earth Resistance Tester	Sesuai
5	Jatuh Tegangan (Voltage Drop, ujung feeder)	Sirkuit Daya Akhir (Final Power Circuit)	≈ 2.15 % (≤ 3 %, PUIL 2020)	≈ 2.15 % (asumsi sesuai desain)	Voltmeter	Sesuai

Based on the design calculations, all tested electrical installation parameters for Workshop 3 and 4 comply with PUIL 2020 standards, including a main feeder load current of approximately 270 A, insulation resistance ≥1 MΩ, grounding resistance of approximately 3.49 Ω (below the 5 Ω maximum limit), and a voltage drop of approximately 2.15% at the circuit end point (below the 3% maximum limit). These values represent design-stage calculations rather than actual field measurements, as installation and commissioning had not yet been carried out at the time this report was prepared. Field verification using calibrated instruments (clamp meter, megger, earth resistance tester, and voltmeter) is recommended once installation is complete to confirm that the as-built condition matches the design results.

IV. CONCLUSION

This study successfully developed an electrical installation design for Workshop 3 and Workshop 4 at PT VME Process based on engineering calculations and applicable electrical standards. The design process included electrical load analysis, cable sizing, voltage drop verification, protection device selection, grounding system design, and Bill of Quantities (BOQ) preparation. The calculation results confirmed compliance with PUIL 2020 across all verified parameters the total demand load of approximately 178 kVA was adequately supported by the installed Main MCB rating of 630 A with a utilization ratio of 43%, the maximum voltage drop of 2.15% remained below the 3% allowable limit, the grounding resistance of approximately 3.49 Ω satisfied the maximum requirement of 5 Ω, and all selected conductors provided adequate current-carrying capacity relative to their protective devices. These results indicate that the proposed electrical installation design meets the required safety, reliability, and efficiency standards for a fabrication workshop environment. Recommendation based on the results of this study, several recommendations are proposed for future implementation and development. First, on-site verification of soil resistivity through a Wenner four-pin test is recommended prior to construction to confirm the assumed grounding design parameters used in this study. Second, periodic testing of the grounding resistance and insulation condition should be conducted after installation to ensure long-term system reliability. Third, future expansion of Workshop 3 and Workshop 4 should consider the available voltage drop margin (approximately 0.85%) and the spare Main MCB capacity (approximately 57%) when adding new electrical loads, to avoid the need for conductor or panel upsizing. Finally, further research may explore the integration of energy monitoring systems to support predictive maintenance of the electrical distribution network at PT VME Process [10].

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