INSOLOGI: Jurnal Sains dan Teknologi
https://journal.literasisains.id/index.php/INSOLOGI
ISSN 2828-4984 (Media Online) | ISSN 2828-4992 (Media Cetak)
Vol. 5 No. 1 (Februari 2026) 204-218
DOI: 10.55123/insologi.v5i1.7506
Submitted: 05-01-2026 | Accepted: 15-01-2026 | Published: 10-02-2026

Electrical System Design for High Rise Building Based on Reliability Index

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Abstract

The research discusses the evaluation of electrical systems in multi-storey buildings, including analysis of compliance with PUIL 2011 standards and integration of Faraday Cage-based lightning protection systems. This study focuses on the Pasar Baru Bandung Building, with the aim of assessing the efficiency and safety of the electrical system used. The research method is carried out through the stages of field observation, data collection, and data processing. Observations were made to identify electrical equipment and assess the feasibility of its use. Data collection includes load capacity and single line diagrams, which are then processed to determine the value of Strong Current Conductivity (KHA) and Drop Voltage. The results of data processing were compared with existing data and analysed based on applicable standards. The results show that the power distribution system in Pasar Baru Bandung Building has been designed with high efficiency, with organised power distribution through main panels and sub-panels. The electrical protection evaluation shows that the grounding and earthing system has met the safety standards to prevent electrical faults. In addition, lightning protection analysis with the Rolling Sphere method ensures that the building's protection against lightning strikes is at an optimal level. The benefit of this study is the comprehensive examination of the electrical system, considering power distribution, protection, and energy efficiency. Despite challenges like inaccuracies in voltage drop measurement due to factors like environmental conditions and equipment age, the research still has a significant impact on improving the safety and efficiency of electrical systems in tall buildings.

Keywords: *Design, Multi-Storey Building, Reliability, Electric Power, Installation.*

1. INTRODUCTION

The electrical distribution system in high-rise buildings is a crucial aspect in ensuring a reliable and efficient supply of electrical energy. The system consists of various components, including transformers, distribution panels, cable ducts, and protection devices that aim to ensure the reliability and safety of electricity supply for occupants and devices in the building (Al-Kodmany, 2022; Shirinbakhsh & Harvey, 2024; Su, Yang, Shen, & Yang, 2023). Along with population growth and rapid urbanization, the construction of high-rise buildings is increasing as a solution to the limited land in urban areas (Nugraha, Tjendani, & Witjaksana, 2024; Tripathi & Sahoo, 2024).

The United Nations (UN) estimates that the world population will reach 8.5 billion by 2030 and continue to rise to 9.7 billion by 2050. This increase in population has implications for the increasing need for supporting infrastructure, including efficient and reliable electricity distribution systems for high-rise buildings (Zhao et al., 2024).

Electricity distribution systems in high-rise buildings have their own challenges compared to low-rise buildings. One of the main obstacles is the limited space for installing renewable energy sources, such as solar panels and small wind turbines (Puntodewo, Oetomo, & Darjanto, 2023). A large floor area to surface area ratio leads to higher energy consumption compared to the energy capacity that can be generated from renewable sources at the building site (Aruna, Suchitra, Rajarajeswari, & Fernandez, 2021; Clavijo-Blanco, González-Cagigal, & Rosendo-Macías, 2024; Manguri, Hassan, Saeed, & Jankowski, 2025). Therefore, energy efficiency strategies are the main focus in the design of electrical distribution systems in high-rise buildings (Guntaryono, Prakasa, Rolalisasi, & Affandy, 2025), including the application of energy-saving technologies (Fontenot, Ayyagari, Dong, Gatsis, & Taha, 2021), automated lighting systems (Shi, Liu, Xian, & Zhang, 2023), as well as the utilization of building materials that can reduce power consumption for cooling and heating (Mamiş & Keleş, 2024).

The reliability of the electricity distribution system is also an important factor that must be taken into account in its design (Mentari, Isnaini, & Sulaiman, 2025). To assess the reliability of an electrical distribution system, several key parameters are used, including the System Average Interruption Frequency Index (SAIFI) and the System Average Interruption Duration Index (SAIDI). SAIFI measures the average frequency of interruptions experienced by customers in a given period, while SAIDI measures the average duration of interruptions that occur (Q. Liu, Nakamura, Yasui, Nakagawa, & Yamamoto, 2024). Several studies have shown that the application of insulator protection can significantly reduce SAIFI and SAIDI values, thereby improving the reliability of the electricity distribution system (Frank et al., 2023). However, existing studies have mostly focused on outdoor distribution networks and have not considered the application of reliability indices in the design of electrical distribution systems for high-rise buildings (Jing, 2023; Zhang, Qian, & Tang, 2022).

Based on the above references, the research focuses on the development of an optimal electrical distribution system design for high-rise buildings, considering reliability index as the primary factor in its design. This reliability-based approach differs from previous studies that have emphasized external distribution networks, with a focus on incorporating reliability parameters in the internal electrical distribution system of high-rise buildings (Ouyang et al., 2024).

The main contribution of this research is to provide a solution in designing an electric distribution system based on reliability indices to enhance the efficiency and stability of the electrical system in high-rise buildings. It is anticipated that the findings of this study will offer practical recommendations for architects and building managers to improve the reliability and energy efficiency in the use of electricity.

Furthermore, this study will also delve into the utilization of Building Information Modelling (BIM) and co-simulation techniques in the planning and analysis of electrical distribution networks. Through the use of this technology, the design of the electrical distribution system can be more accurately devised (Cai, Fu, Meng, Wang, & Wang, 2023; Gilbert, James, Smith, Barr, & Morley, 2021; Q. Liu et al., 2024), so as to reduce the risk of disruptions due to design errors or overloads (Bhosale, Karandikar, & Kulkarni, 2023; Warnakulasuriya, Yushmika, Andrahennadi, & Rodrigo, 2022). A more effective electrical fault mitigation strategy is expected to make electrical distribution systems in high-rise buildings more reliable in facing operational challenges (Ivo, Moraes, & Martins-Britto, 2023; Wang et al., 2025).

Therefore, this research aims to develop an optimal design of internal electrical distribution systems in high-rise buildings by integrating reliability indices such as SAIFI and SAIDI as the main considerations in their design. In contrast to previous research that focuses more on outdoor networks, this research focuses on the application of reliability parameters in the internal electrical infrastructure of the building.

The novelty of this research lies in the integrated approach that combines reliability-based design with the utilization of modern digital technologies, such as Building Information Modeling (BIM) and co-simulation techniques. This integration is expected to improve the accuracy and performance of electricity distribution planning, while minimizing the risk of disruptions and overloads during operations.

The design of electrical systems for high-rise buildings in Indonesia remains predominantly based on standard regulations such as PUIL 2011, which focuses on safety and meeting minimum technical limits (compliance-oriented), but has not yet integrated reliability performance parameters since the planning stage. Conversely, the reliability index-based approach through SAIFI and SAIDI emphasizes performance-based design, where network configuration, redundancy, and protection are determined based on measurable supply continuity targets, thereby proven to enhance distribution system resilience and suppress failure risks in dense building critical loads (Joseph, 2025; Lubis, Erivianto, & Tharo, 2024). In the context of Indonesian high-rise buildings, this approach is increasingly important due to vertical load characteristics, occupancy density, and high dependence on electromechanical systems. The integration of BIM and co-simulation becomes crucial because it enables electrical system modeling directly connected with physical layout and cross-disciplinary coordination, while simultaneously simulating dynamic load profiles and disturbance scenarios for more accurate SAIFI-SAIDI predictions (Naufal & Wibowo, 2025; Sani, Tarigan, & Anisah, 2025). Meanwhile, co-simulation enables simultaneous evaluation between electrical models, dynamic load profiles, and disturbance scenarios to predict impacts on SAIFI and SAIDI values more accurately (Cheng, Stock, Xhonneux, Çakmak, & Hagenmeyer, 2025; Walch et al., 2024). Unlike studies in developed countries that focus on utility smart grids or renewable energy microgrids, this approach targets internal distribution optimization in high-rise buildings within a still-developing national electrical system, thus being more adaptive to Indonesian conditions and supporting the development of reliable and sustainable smart buildings.

The expected outcome of this research is a practical design framework that can be used by architects, engineers, and facility managers in improving the reliability, efficiency, and resilience of electrical distribution systems in high-rise buildings. In the long term, this approach is expected to reduce the impact of electrical faults and support the development of smarter and more sustainable urban buildings.

2. RESEARCH METHODOLOGY

The method used in evaluating the electrical system in this multi-storey building includes several main stages, namely field observation, data collection, and data processing. The electrical system simulation parameters used in this research include system voltage, transformer capacity, load power factor, load factor, and demand factor. In addition, the conductor parameters analyzed include cable type, conductor length, cable installation method, ambient temperature, and correction factors according to PUIL 2011 standards. Operational parameters are also considered, such as daily load profiles, variations in peak load and average load, as well as starting current on motor loads such as elevators, water pumps, and HVAC systems. These parameters are used as input variables in the modeling and simulation of the building electrical system.

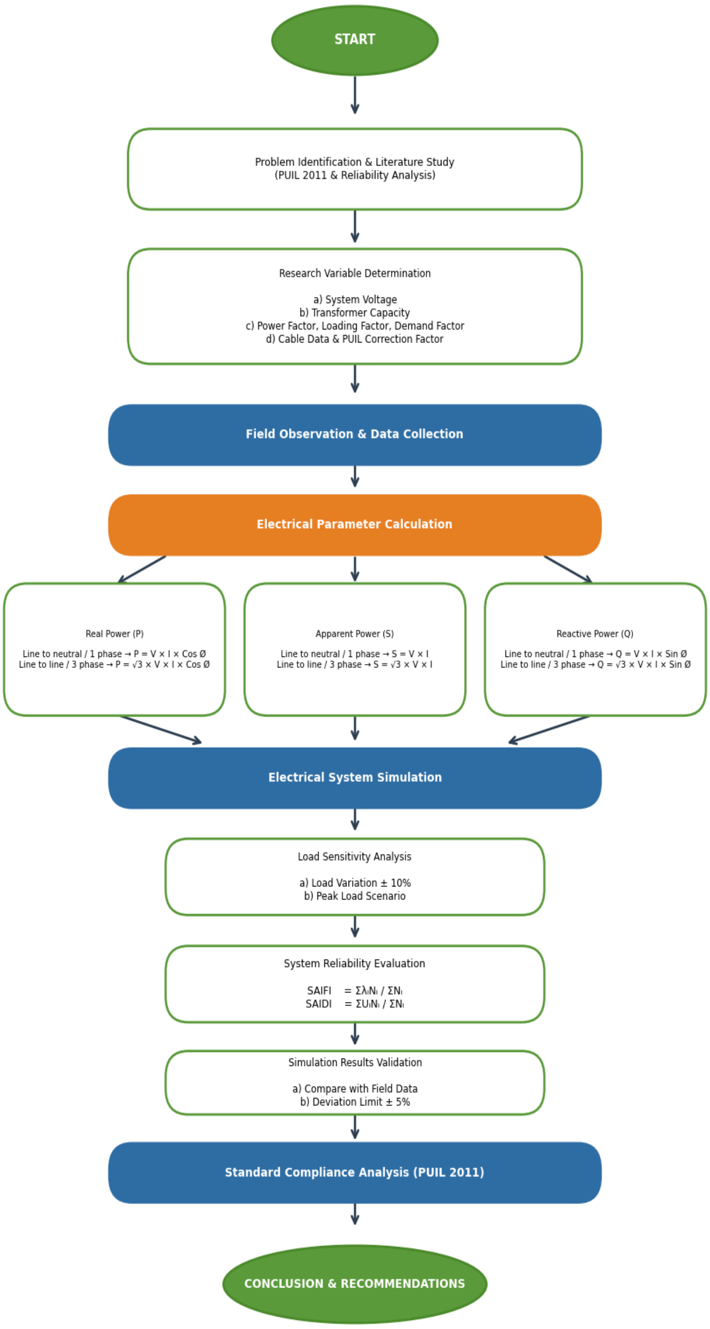

Figure 1. Research Flow Chart

Field observations are carried out to identify electrical equipment in the building and assess the feasibility of its use. This step aims to facilitate the overall electrical system evaluation process. Furthermore, data collection is carried out which includes load capacity data and single line diagrams at the Pasar Baru Bandung Building. After the data is obtained, the next stage is data processing which aims to determine the value of Strong Current Conductivity (KHA) and Drop Voltage. The electrical system simulation results are validated using field measurement data, which includes current measurements at the main distribution panel and voltage measurements at the load side. Validation is performed by comparing the simulation results with actual field data. The tolerance limit for deviation used in this research is ±5% in accordance with the allowable limits in PUIL 2011 standards. This validation process aims to ensure that the simulation model used is capable of accurately representing actual electrical system conditions.

The calculation results are then compared with the existing data and analysed based on PUIL 2011 standards to ensure compliance with applicable regulations. The construction site of this building is located on Jalan Gelora, on a vacant land with the following boundaries: The east side is bordered by Jalan Gelora, the north side is bordered by Puskesmas Gelora, the south side is bordered by the Indonesian Hunting and Shooting Association (PERBAKIN) Field, and the west side is bordered by Jalan Tentara Pelajar.

2.1 Calculation Tables and Formulas

2.1.1 Electrical

Electrical power is divided into three kinds of power as follows:

1) Real Power (P)

Real power is the power required by a resistive load. Real power indicates the flow of electrical energy from the power plant to the load network to be converted into other energy.

Line to netral / 1 phase

$P = V \times I \times \cos Ø$ .... (1)

Line to line/ 3 phase

$P = \sqrt{3} \times V \times I \times \cos Ø$ .... (2)

Desc :
P = Real Power (Watt)
V = Voltage (Volt)
I = Current flowing in the conductor (Amperes)
Cos T = Power Factor

2) Apparent Power (S)

Electrical power that is transmitted through transmission or distribution lines. This power is the product of the voltage and current through the conductor.

Line to netral/ 1 phase

$S = V \times I$ .... (3)

Line to line/ 3 phase

$S = \sqrt{3} \times V \times I$ .... (4)

Desc :
S = Apparent power (VA)
V = Voltage (Volt)
I = Current flowing in the conductor (Amperes)

3) Reactive Power (Q)

Reactive power results from the difference between the apparent power entering the conductor and the active power towards the conductor itself, this power is usually used for mechanics and heat. This reactive power is the result of the multiplication between the amount of current and voltage which is influenced by the power factor.

Line to netral/ 1 phase

$Q = V \times I \times \sin Ø$.. (5)

Line to line/ 3 phase

$Q = \sqrt{3} \times V \times I \times \sin Ø$ .... (6)

Desc :
Q = Reactive power (VAR)
V = Voltage (Volt)
I = Current (Amperes)
Sin T = Power Factor

Shown in Figure 1, the power triangle describes the relationship between real power (P), reactive power (Q), and apparent power (S) in an alternating current (AC) electrical system. Real power is the power that is actually used to perform work, while reactive power describes the power circulated by inductive or capacitive elements in the circuit. These two powers form a triangular relationship with apparent power, which is the vector sum of real power and reactive power. Where the general definition of the Power Triangle is a relationship between real power, apparent power, and reactive power, which can be seen in the triangular shape below:

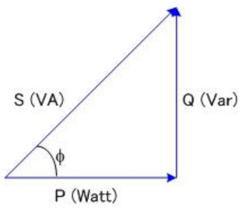

Figure 2. Power Triangle

Where:
P = S x Cos Ø (Watt)
S = √(P2 + Q2) (VA)
Q = S x Sin Ø (VAR)

In addition to referring to compliance with PUIL 2011 standards, this research also considers the reliability aspects of the electrical system. Reliability evaluation is conducted using electric power system reliability indicators such as SAIFI (System Average Interruption Frequency Index) and SAIDI (System Average Interruption Duration Index). This analysis aims to assess the level of electricity service continuity in high-rise buildings, so that the system not only meets technical installation standards but also has good operational reliability.

2.2 Determining Starting and Running Power

For Resistive Load: Power = Amperes x Volt =
For Reactive Loads: Power = Amperes x Volts x Load Factor (Generally large Load Factor = 0.8).

This research uses simulation parameters including system voltage, transformer capacity, power factor, load factor, demand factor, cable type and length, installation method, and ambient temperature according to PUIL 2011 correction factors. The simulation results are validated using field measurement data with a deviation tolerance limit of ±5%. In addition to standard compliance analysis, this research also evaluates system reliability using SAIFI and SAIDI indices. Sensitivity analysis is conducted with load variations of ±10% and peak load scenario simulations to ensure the electrical system remains operating within safe and reliable limits.

3. RESULTS AND DISCUSSION

Analysis of the KONI Building specifications shows that the design of this building has been adjusted to the needs of the function and applicable regulations. With 12 floors and 1 basement, the building is designed to accommodate various activities and a large number of users. The building structure uses reinforced concrete and steel, which is an ideal combination for high-rise buildings because it provides strength, durability, and flexibility in resisting vertical and horizontal loads, such as wind and earthquake loads.

The building height of 52.20 metres indicates that this is a medium-to-high-rise building, which requires careful planning of security and utility systems, including electrical, fire-fighting and air-conditioning systems. With a floor area of approximately 11,443 m², the building has a large enough capacity to accommodate various facilities. The floor divisions, namely 8 functional floors, 2 podium floors, 1 ground floor, 1 mezzanine, and 1 basement, indicate a clear zoning between public areas, operations, and supporting facilities. The basement functions as a parking space or technical space to support building operations, such as mechanical rooms, electrical panels, or storage.

Source of electrical energy comes from PT PLN (Persero) with a voltage of 20 kV which is then channeled to the PLN room for further distribution. From here, electricity is channeled to the Low Voltage Main Panel (LVMDP) through a dry-type three-phase transformer, which reduces the voltage from 20 kV to 380/220 V so that it can be used by various systems in the building. From the PUTR, electricity is distributed to various panels, including the Panel Room which contains the Low Voltage Master Panel (LVMDP). LVMDP functions as the main distribution center that delivers electricity to various parts of the building through other panels. The Floor Panel Room is in charge of managing the distribution of electricity to units such as the Lighting Panel, Power Panel, and PP AC/AHU which play a role in the operation of lighting systems and other electrical equipment. Electricity is then channeled to functional spaces, which include floor outlets, sockets, and lighting fixtures. In addition, there are supporting systems such as pump rooms which include PP Pump and PP Hydrant, as well as PP Yard which distributes electricity to areas outside the building. To ensure continuity of electricity supply, the building is also equipped with a generator as a backup power source that can operate in the event of a power outage from PLN.

The electrical installation uses a cable tray system as the main cable distribution route, which ensures regularity and safety in the flow of electricity to all parts of the building. With a structurally designed distribution system, the KONI building can accommodate large and diverse electricity needs in accordance with its function as a multi-storey building with various facilities. This technical series of electrical installations and building equipment is carried out visually to provide an outline visual description of the feasibility of using electrical installations and building equipment.

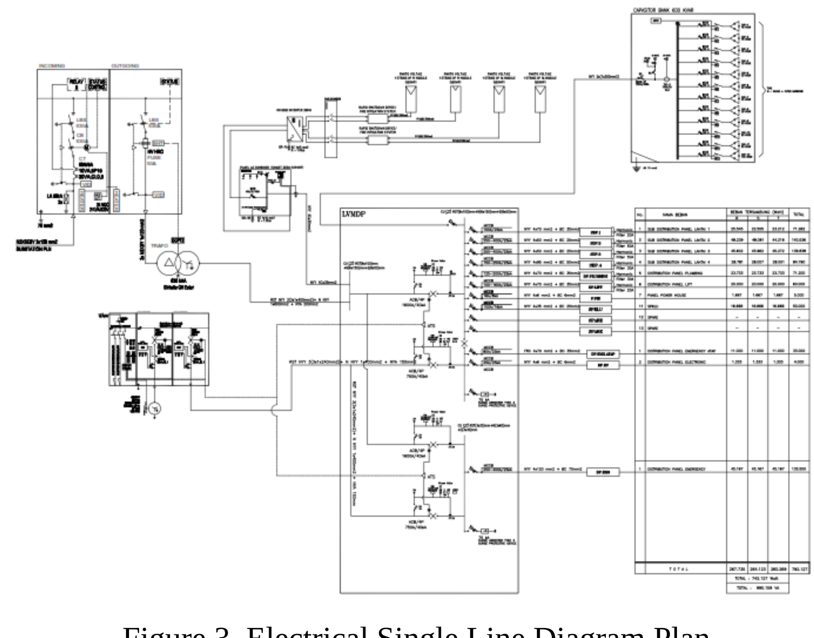

Figure 3. Electrical Single Line Diagram Plan

The data in table 1 shows the maximum load values adjusted by a diversity factor of 1.2, with results of 549,994, 549,994, and 531,358. These values reflect the allowable load limit after considering the variation or non-uniformity factor in the analysed system. The implementation of this analysis can be applied in various fields, especially in building structure planning, civil engineering design, and load management in electrical and mechanical systems. In structural engineering, an understanding of the maximum bearing capacity of building elements is essential to ensure safety and efficiency in various applications. This includes design optimisation to match loads without exceeding material limits, which is an essential factor in civil, electrical and mechanical systems. Structural optimisation techniques, such as size and shape optimisation, are used to improve performance and material efficiency (Manguri et al., 2025). In addition, capacity design principles are applied to ensure the structure can withstand earthquake loads, as applied to steel buildings with braced frames (Vargas & Diaz, 2024).

Table 1 describes the calculation of the total electrical demand for a multi-storey building, including the distribution of electrical loads on various panels and floors. In this table, the installed load in watts for various facilities such as elevators, pump rooms, and pressure fan rooms is shown, as well as the demand factor used in the calculation of the maximum load. In addition, this table also shows the maximum load under various operational conditions, such as when PLN is on, the generator is on, and in a fire situation.

The calculation of the total electrical load is carried out in VA and kVA units, including the minimum load estimation with a diversity of 1.2 to ensure adequate power capacity. In the planning, the electrical connection of the building uses PLN power of 630 kVA with the support of a transformer with a capacity of 800 kVA that uses Static Oil Ester technology. In addition, there is the use of capacitor banks with certain voltage specifications to optimize the power factor. With this calculation, the building's electricity needs can be designed efficiently, ensuring sufficient electricity supply and considering power reserves in emergency conditions such as fire.

Table 1. Calculation of Total Electricity Demand for Multi-storey Building

No.	PANEL	Installed Load (Watt)			Demand Factor	Max Load (Watt)		
	BUILDING UTILITY PANEL	PLN ON	GENSET ON	FIRE		PLN ON NORMAL	GENSET ON NORMAL	PLN & GENSET ON FIRE
1	FIRE LIFT ROOM (BASEMENT)	18.000	18.000		1,25	22.500	22.500	22.500,00
2	LIFT 1 ROOM (ROOF)	15.000	15.000		0,75	11.250	11.250	
3	LIFT 2 ROOM (ROOF)	15.000	15.000		0,5	7.500	7.500	
4	LIFT 3 ROOM (ROOF)	15.000	15.000		0,5	7.500	7.500	
5	LIFT 4 ROOM (ROOF)	15.000	15.000		0,5	7.500	7.500	
6	TRANSFER PUMP ROOM (BASEMENT)	11.000	11.000		1	11.000	11.000	
7	BOOSTER PUMP ROOM (ROOF)	3.000	3.000		1	3.000	3.000	
8	DP EC (ELECTRONICK) – (GROUND)	4.000	4.000		1	4.000	4.000	4000
9	PRESSURE FAN ROOM (ROOF)	7.500	7.500		1	7.500	7.500	7500
10	PRESSURE FAN ROOM (ROOF)	7.500	7.500		1	7.500	7.500	7000

No.	PANEL	Installed Load (Watt)			Demand Factor	Max Load (Watt)		
	BUILDING UTILITY PANEL	PLN ON	GENSET ON	FIRE		PLN ON NORMAL	GENSET ON NORMAL	PLN & GENSET ON FIRE
11	P-PH (GROUND)	5.000	5.000		1	5.000	5.000	
12	SUMP PUMP ROOM (BASEMENT)	37.000	37.000		0,8	29.600	29.600	
13	STP ROOM (BASEMENT)	31.300	31.300		0,8	25.040	25.040	
14	ELECTRIC PUMP ROOM (BASEMENT)	-	-	132.000,00	1			152000
15	JOCKEY PUMP ROOM (BASEMENT)				1	5000	5000	
16	P-SPKLU (GROUND)				0,75	37.500	37.500	
TOTAL	**LV-MDP (BASEMENT)**	**672.77**	**672.77**				**527994**	**510104.1**
Total Load Calculation in VA		**672.77**	**672.77**			**527.994**	**527.994**	**510.104**
Total Load Calculation in kVA		**840.909**	**840.909**			**659.993**	**659.993**	**637.630**
Minimum Load with Diversity 1.2						**549.994**	**549.994**	**531.358**

Connections using PLN 630 kVA
Transformer load 800 kVA (Using Static Oil Ester)
ICB Primary 630 kVA (Prime Power Type Open)
Bank Capacitor 120 kVAR with voltage 400-480 Volt

In electrical systems, a similar concept is applied to distribute loads evenly, thus preventing overloading of the power grid and improving system reliability and safety. Meanwhile, in manufacturing, data on carrying capacity is used to determine the operational limits of machines, ensuring they work within a safe and efficient zone, thus avoiding failures and increasing productivity (Shi et al., 2023). While these methods contribute to improved safety and efficiency, continuous monitoring and adjustment are required to adapt to changing conditions. Therefore, real-time assessment is a crucial aspect in maintaining structural integrity and system performance on an ongoing basis. Small differences in the final values indicate that there is a slight variation in the load that the analysed element can bear. This could be due to differences in material conditions, load distribution or environmental factors that affect system performance. Therefore, understanding these values is important in technical decision-making to ensure efficiency and safety in field implementation.

Reliability evaluation of building electrical systems is not limited to maximum load analysis, but is also extended through internal disturbance scenario simulations to estimate system reliability indices. The indices used are SAIFI (System Average Interruption Frequency Index) and SAIDI (System Average Interruption Duration Index) calculated using the equations $SAIFI = \Sigma\lambda_i N_i / \Sigma N_i$ and $SAIDI = \Sigma U_i N_i / \Sigma N_i$, where λ_i is the failure rate, U_i is the disturbance duration, and N_i is the proportion of affected load. Based on the building system configuration using 20 kV PLN supply, 800 kVA transformer, LVMDP distribution, and genset backup system, disturbance simulations such as transformer failure with an assumed disturbance frequency of 0.2 times per year and average repair time of 3 hours show estimated internal SAIFI values of approximately 0.14 disturbances per year and SAIDI of approximately 0.42 hours per year. These results indicate that although power capacity is sufficient, supply redundancy, protection coordination, and genset system reliability greatly influence the maintenance of electricity service continuity, especially for critical loads such as fire elevators, hydrant pumps, and emergency ventilation systems.

The modeling of the electrical system of a multi-storey building showing the power distribution structure in a multi-storey building, which consists of various layers of electrical distribution from the main source to each floor or zone in the building. The presence of various protection components such as circuit breakers and protection relays emphasizes the importance of system reliability in reducing potential electrical faults. In the context of the electrical system diagram shown, several modelling aspects such as lightning protection, building-to-grid integration, fault diagnosis techniques, and the use of Building Information Modeling (BIM) contribute to reducing SAIDI and SAIFI values. For example, protection against lightning strikes using parameterised distribution models can help reduce disturbances due to surges, which if not controlled can increase the duration and frequency of outages (Mamiş & Keleş, 2024).

In addition, the integration of building electrical systems with the grid (building-to-grid) allows for better optimisation of power distribution and load management. With the presence of energy storage systems such as batteries, power interruptions from the main grid can be reduced, ultimately lowering SAIDI and SAIFI values (Kisuule, Hernando-Gil, Serugunda, Namaganda-Kiyimba, & Ndawula, 2021). ELM-based fault diagnosis techniques also play a role in improving the response to faults by detecting problems sooner, resulting in shorter recovery times and a reduced SAIDI index (G. Liu, 2023).

Furthermore, the use of Building Information Modelling (BIM) and co-simulation techniques allows for more accurate planning and analysis of the electricity network. With three-dimensional digital models, electricity distribution systems can be designed more efficiently so that the risk of disruption due to design errors or overloading can be minimised (Shen, 2024). The co-simulation approach also enables more complex analyses of system performance, so that fault mitigation strategies can be implemented more effectively (Frank et al., 2023). Thus, the application of technology in the modelling of electrical systems in high-rise buildings plays a role in improving the reliability of the electrical system, which directly impacts the reduction of SAIDI and SAIFI values. This shows that the optimisation of power distribution design and the application of advanced technology not only improve energy efficiency, but also significantly reduce the impact of electrical faults on users.

When compared to international standards such as IEEE Std 493 for electric power system reliability evaluation and IEC 62305 for lightning protection systems, the building electrical system design shows compliance in aspects of backup supply redundancy, grounding system performance, and risk-based lightning protection implementation. Further, the integration of Building Information Modeling (BIM) and co-simulation strengthens design validation through digital system performance testing under various operating conditions. This demonstrates that the design approach used not only meets national standards but also has global competitiveness in reliability-based high-rise building electrical system design and disturbance risk mitigation.

The power distribution in multi-storey buildings shows a hierarchical pattern with the main panel distributing power to various sub-panels on each floor. The main lines marked with red lines serve as the primary distribution lines, while the secondary lines connect the electrical loads to each distribution point. This pattern shows a structured system design to ensure efficiency and even distribution of power throughout the building.

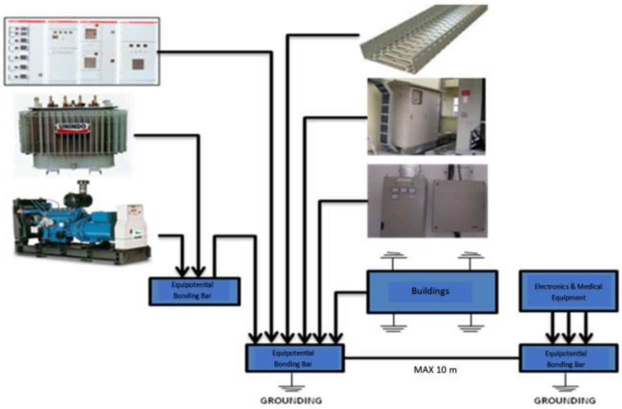

Figure 4. Illustration of Electrical Grounding Flow in the Building

According to PUIL 2011, the minimum cross-sectional area of protection conductors must meet certain standards to ensure the safety of the electrical system.

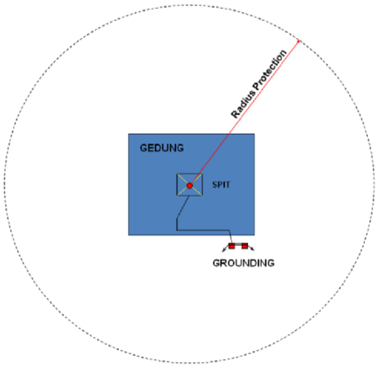

Figure 5. Protection Radius of Lightning Protection Installation

Figure 4 shows the concept of the protection radius of a lightning protection installation to protect a building from lightning strikes. The illustration shows a building with a lightning protection system (SPPT) and grounding. The formula $Rp = \sqrt{h (2D - h) + DL (2D + DL)}$ is used to calculate the protection radius based on the system height (h), distance (D), and protection factor (DL). This calculation ensures that the lightning rod system works optimally in reducing the risk of direct strikes.

Table 2. Calculation of Protection Radius of Lightning Protection Installation

Where h > 5 m
h (m) = Height of Lightning Rod above the protected area
D (m) = Lightning strike area, D = 20m, 45m, or 60m
DL (m) = 106 DT (msec)

	System 1				System 2	
Protection Level	**1**	**2**	**3**	**1**	**2**	**3**
h =	19.83	19.83	19.83	19.83	19.83	19.83
D =	20	45	60	20	45	60
DL =	50	50	50	70	70	70
Rp2 =	4899.9711	8391.4711	10486.3711	8099.9711	12591.4711	15286.3711
Rp =	70.00	91.60	102.40	90.00	112.21	123.64

Based on table 2, it can be concluded that the lightning protection system used in this building is a Faraday Cage system with a conventional configuration. This system is designed to protect buildings from direct and indirect lightning strikes by adopting applicable standards, such as SNI IEC 62305-1:2013, SNI IEC 62561-4:2012, and SNI 03-7015-2004. In the protection analysis, it is determined that the appropriate level of protection for this building is Protection Level 1, which is the highest level of protection. This is based on the calculation of the frequency of direct strikes (Nd) which reaches 118.98 strikes, as well as risk analysis based on factors such as the type of building, the number of people in it, and the potential damage that can occur due to lightning strikes. The calculation of protection efficiency (Ec) shows that the value of Nd is greater than Nc, so this building does require an effective lightning protection system. Therefore, the Rolling Sphere method is used with a protection radius of 20 metres, in accordance with applicable protection standards.

From the calculation results in table 2, it can be seen that Rp and Rp2 in System 2 are higher than System 1, especially at Protection Level 3. This shows that in System 2, the protection coverage is wider and stronger than System 1. So it can be concluded that the use of the Faraday Cage lightning protection system with the Rolling Sphere method is the right step to ensure maximum protection of buildings from potential lightning strikes. From an engineering risk perspective, the protection results of the Rolling Sphere method also correlate with mitigation of potential financial losses. Voltage surges caused by lightning induction can damage sensitive electronic equipment such as Building Management System (BMS), elevator control panels, communication systems, and data servers. Although not causing structural building damage, transient overvoltages can result in operational downtime, data loss, and high-value equipment replacement costs. Therefore, the application of the Rolling Sphere lightning protection method not only enhances building structural safety but also plays a role in reducing operational risks and economic losses in modern buildings that are highly dependent on electronic and automation systems.

This result is in line with the statement (Zamani, Tajahmadi, & Jamali, 2022) that the Rolling Sphere Method offers a comprehensive approach in determining the radius of protection and the height of the air terminal, thus increasing the effectiveness of the lightning protection system. The application of this method enables more accurate calculations of the protection system dynamics, overcoming the limitations of conventional approaches that rely on graphical representations (Ma, 2021). In addition, the Rolling Sphere has been widely applied in a variety of architectural contexts, including in historic buildings, proving its flexibility and effectiveness in various structural conditions.

4. CONCLUSION

The KONI Building has been designed in accordance with functional requirements and applicable regulations, with reinforced concrete and steel structures that provide strength, durability, and flexibility in resisting vertical and horizontal loads. With a height of 52.20 metres and a floor area of approximately 11,443 m², the building has clear zoning between public areas, operations, and supporting facilities. The main electrical system uses a power source from PLN with a voltage of 20 kV distributed through a dry type three-phase transformer system, ensuring stable electricity availability. The power distribution system is organised hierarchically through main panels and sub-panels to ensure efficiency and safety of electricity distribution to all parts of the building. In addition, the building is equipped with a generator as a backup power source.

From the protection aspect, the grounding and earthing system follows the PUIL 2011 standard to ensure the safety of the electrical system against fault currents and voltage surges. Lightning protection analysis shows that the system used is the Faraday

Cage with Rolling Sphere method, which complies with national standards and has the highest level of protection (Level 1). The use of this method is able to provide maximum protection to the building from potential lightning strikes, with a wide protection coverage. Overall, this research confirms that the design and implementation of structural, electrical, and protection systems in the KONI Building has been designed with careful planning. This study furthers comprehension of integrated building system design somewhat effectively in multi-storey public buildings mostly within Indonesia's peculiar urban settings. This supports the building's operational reliability, energy efficiency, and safety for its users. Future public building designs might benefit from these findings which could improve sustainability and enhance operational safety significantly over time naturally.

Although this research provides valuable insights, there are some limitations. Firstly, this study only focuses on the KONI Building, so the results may not be fully generalisable to all types of buildings with different characteristics. Secondly, this study focuses more on design and implementation analysis without direct experimental tests of the structural resistance and effectiveness of lightning protection under actual conditions. Thirdly, although this study addresses electrical power distribution, aspects of energy efficiency and sustainability in the long term have not been comprehensively analysed. Fourth, external factors such as climate change and its impact on material durability or electrical system performance have not been the focus of this research. For future research, it is recommended that experimental testing of lightning protection performance, environmental impact analysis, and comparison with similar buildings are conducted to increase the validity and generalisation of the research results.

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