

Study Analysis of Voltage Drop in a Typical Office Building Lighting System: A Case Study of of FEM IPB Building Electrical Installation

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Design of electrical system in the Faculty of Economics and Management Bogor Agricultural Institute was based guidance consisting of PUIL, SNI, as well as provisions of modern security and technology and aesthetic beauty. Design is also based on the relevant IEC standards, specifically IEC 60364. In the electrical system, it is necessary to pay attention to the conductor and safety factor to minimize power losses and drop voltage. Losses on the customer side due to drop voltage besides damaging electrical equipment is customers only can have a voltage less than 220 V. The distance between load panel and main panel is directly proportional to the drop voltage value, much farther the load panel to the main panel, resulting greater drop voltage value produced. The calculation of drop voltage based on total load, length, and area of conductor. To overcome the problems that occurred in this case study, the conductor uses 1.25 times the nominal current as a safety factor. The selection area of conductor can be said to be quite good with the farthest drop voltage value from SDP-TR is 0.89%. The total amount of electricity in the building is 158.33 kVA, assuming that if there is an additional 5-10 years, the total electric power and 15% of the others SDP is 182.04 kVA.

Keywords— electrical work planning, PUIL, SNI, IEC

I. INTRODUCTION

A good electrical installation aims to ensure human safety from the danger of electric shock, the safety of electrical installations and their equipment, the safety of buildings and their contents from electric fire, and environmental protection [1]. Quality and safety will only be guaranteed if the design is carried out by the latest regulations, electrical equipment that complies with relevant product standards, initial checks on standards and regulations have been achieved and recommended periodic installation checks.

The energy efficiency of a building's electrical installation system is influenced by two aspects, namely power losses or losses on the cable and the efficiency of the equipment used [2]. Voltage drops will occur along the line that is passed during the transmission of electricity both transmission and distribution. Different parts of the voltage in a power system cause a voltage drop and are also influenced by several factors such as resistance, reactance,

and impedance in the line. The voltage drop on the line is the difference between the voltage at the base of the shipment and the voltage at the receiving end of electricity [3]. The problem that often occurs in the field until now is the voltage drop that exceeds the established tolerance limit. To minimize the voltage drop on the line, it can be done by increasing the selection of the conductor cross-section size used.

II. LITERATURE REVIEW

A. Calculation of Lighting Installation

The stages of lighting installation calculation are as follows:

1. Determine data size from room planning.
2. Determine minimum lighting levels based on applicable standards (BSN, 2011).
3. Determine the planned lighting level (F total),

$$F_{total} = \frac{E \times A}{K_p \times K_d} \text{ (lumen)} \quad (1)$$

Where:

E = Minimum lighting level (lux)

A = Area of work (m²)

K_p = Usage coefficient

K_d = Depreciation coefficient.

4. Determine the type of lamp that will be used.
5. Determine the number of lamp armatures (N total),

$$N_{total} = \frac{F_{total}}{F_1 \times n} \quad (2)$$

Where:

F total = planned lighting level (lumens)

F₁ = One lamp flux (lux)

n = Number of lights in one armature (pieces)

B. Current Conduct Ability

The cross-sectional area of conductors in an electrical installation is determined based on the current passing through the conductor using the equation:

- a. single phase alternating current

$$I = \frac{P}{V \times \cos \varphi} \text{ A} \quad (3)$$

- b. three-phase alternating current

$$I = \frac{P}{\sqrt{3} \times V \times \cos \varphi} \text{ A} \quad (4)$$

Where:

I = Nominal current (A)

P = Active power (W)

V = Voltage (V)

Cos φ = Power factor

The conductivity of the current used in the selection of conductors is 1.25 times the amount of current that passes through the conductor based on PUIL 2000. After knowing the conductivity of the current, the next step is to adjust the catalog to find the appropriate conductor cross-sectional area.

C. Protection

MCB and MCCB function as safety short-circuit current and overload. The capacities of MCB and MCCB are chosen by knowing the ability to conduct a circuit breaker current which is 1.45 times the nominal current based on PUIL 2011. Nominal current is known by Equations (3) and (4).

D. Voltage drop

Voltage drop is the amount of loss caused by resistance and reactance in a conductor. Calculation of voltage drop (ΔU) and the percentage loss refers to the electrical installation guide book published by Schneider Electric with the equation:

$$\Delta U = \sqrt{3} \times I_n \times [(R \cos \varphi) + (X \sin \varphi)] \times L \quad (5)$$

$$\text{in \%} = \frac{100 \times \Delta U}{U_n} \quad (6)$$

Where:

ΔU = Conducting voltage drop (V)

I = Strong conductance current (A)

(R Cos φ + X Sin φ) = Resistance and conductance of conductor (Ω / km)

L = length of conductor (km)

U_n = Phase to phase voltage (V)

III. METHOD

The Faculty of Economics and Management building is located at the Bogor Institute of Agriculture with a view of the building that can be seen in Figure 1 which consists of 4 floors with the total area of the building located on a land area of around 1.22 hectares.

The required data such as building layout drawings, the overall area of the building, the floor plan, the function of the room and the system of each floor to obtain the capacity of the transformer and generator set. The distribution system in planning allows the load point to be served from two directions of electric power sources, namely the supply of PLN and generator sets, so that continuity of service is guaranteed, and the power quality is better because the voltage losses and power losses on the channel become smaller.



Figure 1. Faculty of Economics and Management Building

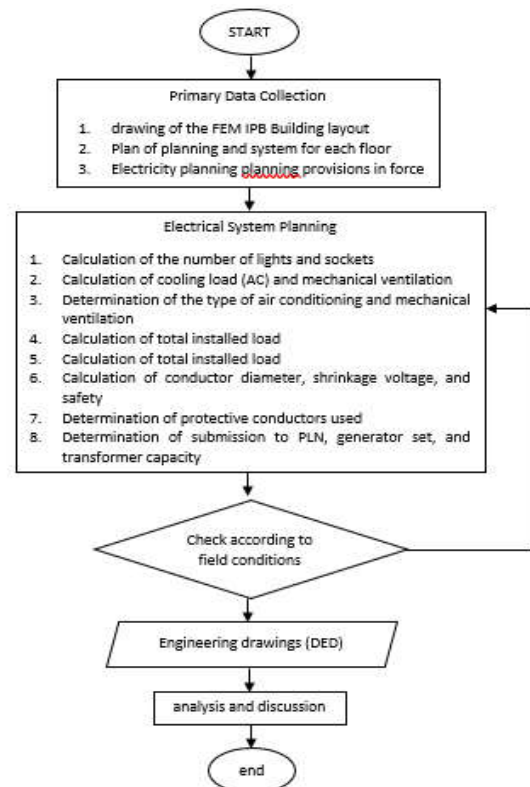


Figure 2. Building planning flow chart

Table 1. Function and area of each floor

Floor	Room	Area (m ²)
1	Discussion Room	81,0
	lecture hall	121,5
	lecturer waiting	40,5

Floor	Room	Area (m ²)	
	room		
	court room	162,0	
	Toilet 1	5,0	
	Toilet 2	4,1	
	Toilet 3	5,0	
	Toilet 4	4,1	
	kitchen	6,0	
	Panel room	6,0	
	women's toilet	23,2	
	men's toilet	23,3	
	student secretariat	46,8	
	the hallway 1	305,9	
	the hallway2	283,8	
	2	examination room1	40,5
examination room2		40,5	
Seminar room		121,6	
staff room		80,9	
treasurer room		28,5	
the department secretary's room		17,9	
living room department		35,9	
the department chair's room		22,6	
Janitor		2,1	
Toilet 1		5,0	
Toilet 2		4,1	
Toilet 3		4,37	
Toilet 4		5,0	
Toilet 5		4,1	
Kitchen		6,0	
Panel Room		6,0	
women's toilet		23,2	
men's toilet		23,3	
student secretariat		46,8	
the hallway 1		305,9	
the hallway2		283,8	
3		lecture hall 1	121,5
		lecture hall 2	121,5
	lecturer room 1	20,2	
	lecturer room 2	20,2	
	lecturer room 3	20,3	
	lecturer room 4	20,1	
	lecturer room 5	20,1	
	student room	40,5	
	Islamic Prayer Room	20,3	
	ablution room	2,3	
	Toilet 1	5,0	
	Toilet 2	4,1	
	Toilet 3	2,7	
	Toilet 4	4,1	
	Panel room	6,0	

Floor	Room	Area (m ²)
	women's toilet	23,2
	men's toilet	23,3
	student secretariat	46,8
	the hallway 1	305,9
	the hallway2	283,8
	4	lecturer room 1-17
Islamic Prayer Room		16,2
ablution room		3,4
Toilet 1		3,4
Toilet 2		3,4
Toilet 3		3,4
R. Dapur		6,9
R. Panel		6,9
Koridor		72,8
R. Umum		40,4
women's toilet		23,2
men's toilet		23,3
student secretariat		46,8
the hallway		283,8

IV. RESULT AND DISCUSSION

A. Lightning Installation

Most types of rooms in the electrical design of buildings are square-shaped with different room functions. The number of light points needed for each room depends on the function and area of the room. Calculation of the number of armature and lights in the room is intended to get a good level of lighting. Reference for use of armature and lamps using Philips product catalog. The following is an example of the calculation of lighting in a room taken as an example of the 1st-floor discussion room.

Room data:

Room length (p)	= 9 m
Room width (l)	= 9 m
Room height (h)	= 4.5 m
Kp (new building)	= 0.9
Kd (BSN, 2001)	= 0.8
E (classroom)	= 350 lux

With Equation (1) a total flux of

$$F_{\text{total}} = \frac{350 \times (9 \times 9)}{0,9 \times 0,8} \quad (7)$$

$$= 39375 \text{ lumen}$$

The type of lamp used is the MASTER TL-D Secura Philips Lighting 36 W with F1 of 3200 lumens. With Equation (2), the number of armatures/lights is obtained,

$$N_{\text{total}} = \frac{39375}{3200 \times 2}$$

$$= 6,15 \rightarrow 12 \text{ lamp}$$

The number of armatures in the discussion room on the 1st floor is 6 pieces or 12 lamps 36 W. The results of laying the number of lighting lamps are shown in Figure 3.

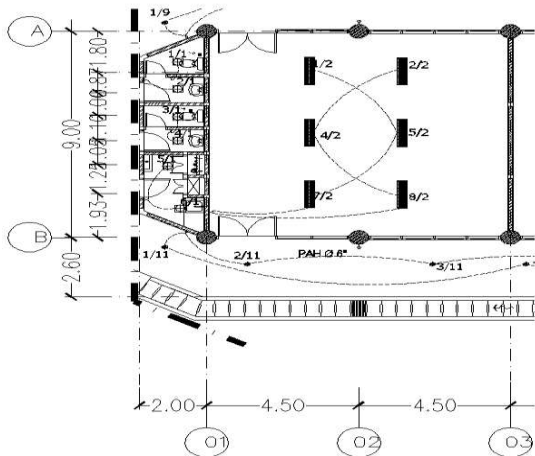


Figure 3. 1st floor discussion room lighting installation

B. Determination of Electric Power

The results of the calculation of electric power per floor are shown in Table 2.

Tabel 2. Building electrical power

Floor	power equipment (VA)				Total power equipment (VA)
	Lamp	AC	EF	Socket Outlet	
1	5335	29506,25	130	5500	40471,25
2	5173,75	28806,25	146,25	7250	41376,25
3	5695	28297,5	130	6000	40122,5
4	3885	19171,25	130	11500	34686,25
SDP reserve	Other backup equipment if needed to develop 15% of the total VA				23498,43
Total VA + VA SDP reserve					180154,68

The total electric power of the Faculty of Economics and Management Building is 156.65 kVA. Assuming an additional 15% of the total power for the reserve SDP, the building's total electrical power is 180.15 kVA. Based on the calculation of total power, the selected step down transformer has a capacity of 200 kVA (Trafindo, 2013) and a generator set with a capacity of 200 kVA open type (Komatsu, 2017).

C. Calculation of Conductional Cross-sectional Area

As an example of the calculation of the conductor cross-sectional area is the main conductor of SDP-TR to PP floor 1. Calculation methods applied include:

1. Determine the nominal current

Using Equation (4), the nominal current of the conductor is, Sebagai contoh untuk perhitungan luas penampang penghantar adalah penghantar utama SDP-TR ke PP lantai 1. Metode perhitungan yang diterapkan meliputi:

$$I_n = 6.655 / (\sqrt{3} \times 380) \\ = 10,11 \text{ A}$$

2. Determine the type and capacity of the MCB / MCCB

Determination of the safety current rating can be determined by calculating the nominal current flowing in the circuit. Calculation of the safety current rating is based on PUIL 2011 pages 80-82,

$$I_{MCB/MCCB} = 1,45 \times 10,11 \text{ A} \\ = 14,66 \text{ A}$$

Calculation of circuit breakers refers to SNI IEC 60898-1: 2009 concerning overcurrent protection for installation. Then the MCB used is the MCB iC60N 3P 20 A, with a disconnection capacity of 10 kA.

3. Determine the conductor cross-section

Based on the safety current obtained by the KHA of,

$$KHA = 1,25 \times 25 \text{ A} \\ = 31 \text{ A}$$

From the calculation, the maximum current that can pass through the conductor is 31 A, so that the appropriate cable for use is NYY 4x6 mm² (Voksel Electric, 2011). With a maximum current capacity that can be received if the installation in the air is 44 A, while the installation in the ground is 52 A. Calculations using the same method are carried out for all building installations. Types of conductors used at the Faculty of Economics and Management Building are NYM, NYY, N2XSEFGbY, and N2XSY.

D. Voltage Drop Calculation

The calculation of the biggest voltage drop in the Faculty of Economics and Management Building is from the farthest distance from SDP-TR to PP 4th floor. By using Equation:

$$R \cos \varphi + X \sin \varphi = 3,002 \Omega/\text{km} \\ L = 38,5 \text{ m} = 0,0385 \text{ km}$$

By using Equations (5) and (6) a voltage drop of

$$\Delta U = \sqrt{3} \times 17,02 \times 3,002 \times 0,0385 \\ = 3,4 \text{ V}$$

So the percentage of voltage drops is,

$$I_n \% = \frac{100 \times 3,4}{380} \\ = 0,89 \%$$

The voltage drop value obtained does not exceed that required by IEC 60364-5-52 which is 3% for low voltage lighting circuits. The results of the voltage drop calculation for each electrical panel are shown in Table 3.

CONCLUSION

From the results of electrical system calculations that have been carried out, it can be concluded that:

1. The total electrical power of the building is 180.15 kVA with the selection of 200 kVA step down transformer and 200 kVA generator set with open type.
2. From the voltage drop calculation data it appears that the farther the distance of the load panel to the main panel, the greater the voltage drop value. For maximum voltage

drop occurs in the panel farthest from the main panel that is 0.89% or 3.4 V.

(4) the nominal current obtained from SDP-TR to PP 4th floor is equal to

$$I_n = \frac{11.205}{\sqrt{3} \times 380}$$

$$= 17,02 \text{ A}$$

The assumption used is,

$$\cos \varphi = 0,8 \text{ kabel NYY } 4 \times 6 \text{ mm}^2$$

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Tabel 3. Calculation of building voltage drop

Location	load classification	conductor				Voltage drop	
		Conductor option	Resistance (Ω/km)	Inductance (mH/km)	Inductive Reactance (Ω)	Length (km)	ΔU (V)
1 st Floor	LP/PP LT.1	NYY 4 x 6 mm ²	3,685	0,288	0,09043	0,025	1,31
	LP/PP NODE LT.1	NYY 4 x 4 mm ²	5,516	0,303	0,09514	0,025	1,22
	VAC LT.1	NYY 4 x 25 mm ²	0,87	0,255	0,08007	0,025	1,32
	VAC NODE LT.1	NYY 4 x 2,5 mm ²	8,866	0,304	0,09546	0,025	1,17
2 nd Floor	LP/PP LT.2	NYY 4 x 6 mm ²	3,685	0,288	0,09043	0,0295	1,92
	LP/PP NODE LT.2	NYY 4 x 4 mm ²	5,516	0,303	0,09514	0,0295	1,45
	VAC LT.2	NYY 4 x 25 mm ²	0,87	0,255	0,08007	0,0295	1,52
	VAC NODE LT.2	NYY 4 x 2,5 mm ²	8,866	0,304	0,09546	0,0295	1,38
3 rd Floor	LP/PP LT.3	NYY 4 x 6 mm ²	3,685	0,288	0,09043	0,034	1,87
	LP/PP NODE LT.3	NYY 4 x 4 mm ²	5,516	0,303	0,09514	0,034	1,67
	VAC LT.3	NYY 4 x 25 mm ²	0,87	0,255	0,08007	0,034	1,72
	VAC NODE LT.3	NYY 4 x 2,5 mm ²	8,866	0,304	0,09546	0,034	1,60
4 th Floor	LP/PP LT.4	NYY 4 x 6 mm ²	3,685	0,288	0,09043	0,0385	3,40
	LP/PP NODE LT.4	NYY 4 x 4 mm ²	5,516	0,303	0,09514	0,0385	1,89
	VAC LT.4	NYY 4 x 16 mm ²	1,376	0,255	0,08007	0,0385	2,15
	VAC NODE LT.4	NYY 4 x 2,5 mm ²	8,866	0,304	0,09546	0,0385	1,81

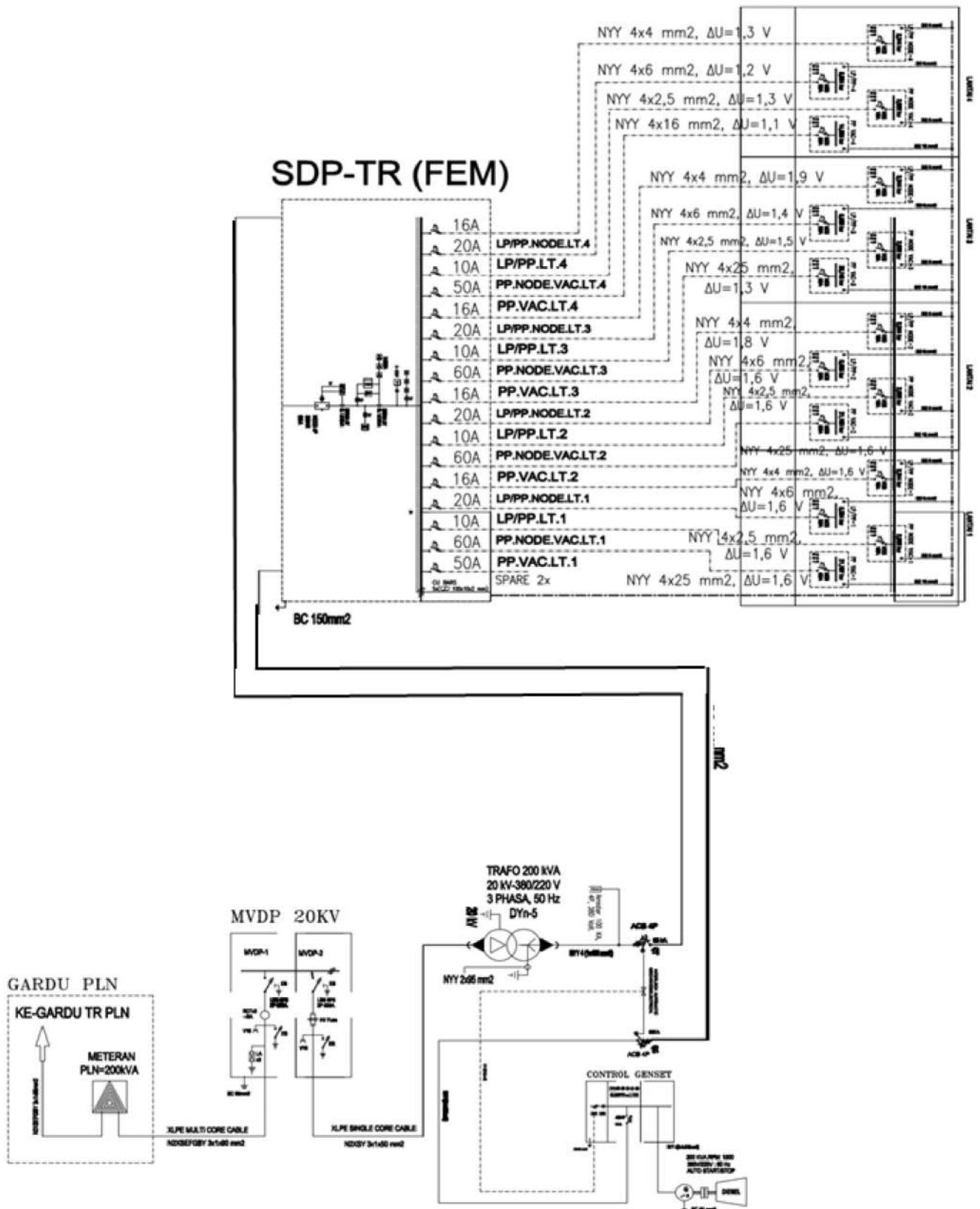


Figure 4. Electrical distribution diagram of the Faculty of Economics and Management Building