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Distribution Transformer Capacity Planning Based On Load Characteristics According To Electric Power Requirements At The Mugarsari Campus, Siliwangi University

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Abstract

Siliwangi University is currently building a second campus in the Mugarsari Tasikmalaya area. With the construction of this second campus, it is necessary to plan the transformer capacity in accordance with the installed electrical power requirements. In terms of designing electrical installations and the need for electrical power to be installed, proper planning is needed. In this research, the distribution transformer capacity value planning has been carried out in accordance with the installed electrical power requirements by considering load characteristics, namely demand factors and diversity factors. The aim of this research is to determine the capacity of the distribution transformer along with an analysis of the distribution transformer loading so that it complies with PLN standards. The total installed load is 1,566 kVA. In this study, calculations were carried out based on load characteristics, namely diversity factors and needs factors. The distribution transformer capacity obtained by considering load characteristics is 1,220 kVA with a loading percentage of 81% . The results of the loading that have been carried out are still in accordance with the Electricity Planning Projections through the 2020 RUPTL.

Keywords: Distribution Transformer; Electric Power; Transformer Loading

1. Introduction

The need for electrical power in an industry must be adjusted to the productivity conditions of the company itself, the most important of which is continuity and high reliability in its service [1]. Not only that, you also need to pay attention to the loading of the transformer so that the transformer doesn't get damaged quickly. In accordance with the Electricity Planning Projections through the 2020 RUPTL, transformer loading is limited from 70% to 90% to maintain the lifetime of the transformer [2].

A transformer is a device that can change alternating current (AC) electrical power from one voltage level to another voltage level with the same frequency through the performance of a magnetic coupling based on the principle of electromagnetic induction [3]. Based on their use, transformers are grouped into: Power Transformers, Distribution Transformers, Measurement Transformers [4]. Distribution transformers are included in the small transformer category [5].

Distribution transformers are generally designed to be overloaded during peak loads on the circuit and are susceptible to failure without proper monitoring [6]. Distribution transformers need to be widely located near residential buildings [7].

A distribution transformer is said to be overloaded if the transformer load exceeds 80% of its rated power capacity or nominal current (I_n) [8]. If the transformer experiences overload, the insulation on the transformer will be damaged due to

excessive heat [9]. Transformers can be loaded more than 80% but must provide a K2 value (overload ratio) of no more than 1.5 at an ambient temperature of ≤30℃ [10].

Currently, Siliwangi University is building a second campus in the Mugarsari Tasikmalaya area. With the construction of this second campus, it is necessary to plan transformer capacity based on installed electrical power requirements. Based on data in the field, currently two distribution transformers have been installed. Judging from the installed power requirements, the two distribution transformers will not be able to meet future electrical power requirements.

The aim of this research is to calculate the capacity of distribution transformers based on the characteristics of the installed load (diversity factor and demand factor) [1], where later the calculated capacity will be readjusted to the available capacity in accordance with SPLN D3.002-1:2007 [11]. Determination of diversity factors and demand factors can be done based on the use of electrical loads, which can be classified based on their operational characteristics. The load classifications include Continuous Load, Intermittent Load, and Standby Load [12].

Another objective is to calculate the distribution transformer loading so that it is in accordance with the RUPTL, namely 70% to 90%. The stages of this research begin with analyzing the electrical power requirements for all buildings on the Mugarsari Campus, then calculating the capacity of the distribution transformer and finally calculating the loading of the distribution transformer so that it meets standards [13].

2. Methods

The research flow in this research can be seen in Figure 1:

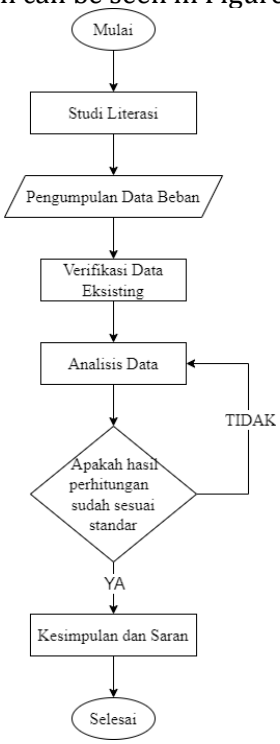

Figure 1. Research flow

The research began by collecting load data on every building that exists or has a DED at the Mugarsari Campus. For an explanation of load data collection, see Figure 2. Flow of Load Data Collection. Next, data analysis is carried out, which is divided into 3 parts, namely: analysis of electrical power requirements, analysis of distribution transformer

capacity calculations, and analysis of distribution transformer loading. Next, the calculation is adjusted to the SPLN [14].

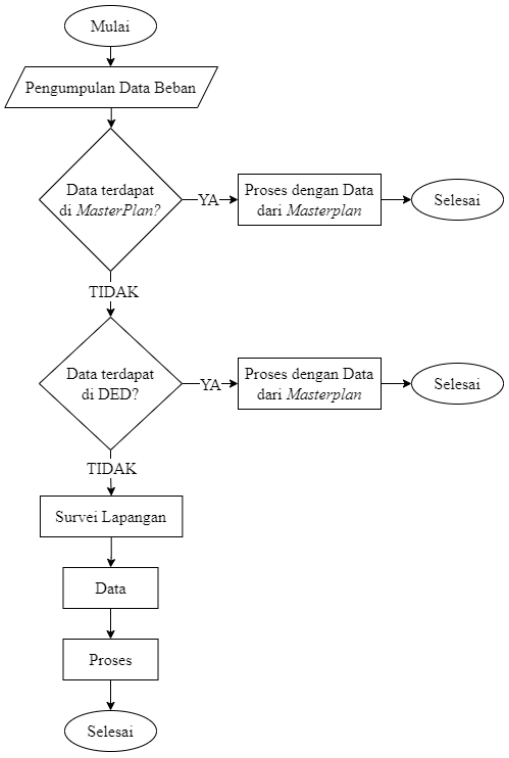

Figure 2. Load Data Collection Flow

3. Results and discussion

Analysis of Electrical Power Needs at the Mugarsari Campus, Siliwangi University
The need for electrical power at the Mugarsari Campus of Siliwangi University can be seen from the electrical load installed in each existing building and can be seen from the planning data for the electrical load that will be installed in buildings that are still under construction or buildings that will be under construction.

1. Rectorate Building

The Rectorate Building has three floors with a total floor area of 64 m × 34 m = 2,176 m ^{2}. The total electrical load power installed in the Rectorate Building is 169,865 kW or 183,718 kVA.

2. Mugarsari Mosque Building

The Mugarsari Mosque building has two floors with a total floor area of 30 m × 25 m = 750 m ^{2}. The total installed electrical load power is 5,762 kW or 5,834 kVA.

3. Multipurpose building

The Multipurpose Building has four floors and a basement with a total floor area of 56 m × 38 m = 2,128 m ^{2}. The total electrical load power installed in the Multipurpose Building is 63,114 kW or 66,486 kVA.

4. Main Building of the Faculty of Agriculture

The Faculty of Agriculture building has four floors with a total floor area of 27 m × 22 m = 594 m ^{2}. The total electrical load power installed in the Main Building of the Faculty of Agriculture is 96,682 kW or 106,608 kVA.

5. Pertamina Building, Faculty of Agriculture

The Pertamina Faculty of Agriculture building has two floors with a total floor area of 29 m × 11 m = 319 m ^{2}. The total electrical load power installed in the Pertamina Building, Faculty of Agriculture, is 11,467 kW or 12,143 kVA.

6. Faculty of Agriculture Canteen Building

The Faculty of Agriculture Canteen Building has one floor with a total floor area of 7 m × 11 m = 77 m ^{2}. The total electrical load power installed in the Faculty of Agriculture Canteen Building is 3,120 kW or 3,298 kVA.

7. Faculty of Agriculture Mosque Building

The Faculty of Agriculture Mosque building has one floor with a total floor area of 15 m × 15 m = 225 m ^{2}. The total electrical load power installed in the Faculty of Agriculture Mosque Building is 6,636 kW or 7,098 kVA.

8. Faculty of Agriculture Secretariat Building

The Secretariat Building of the Faculty of Agriculture has 4 buildings with a total floor area of m ^{2}. The total electrical load power installed in the Secretariat Building of the Faculty of Agriculture is 4,040 kW or 4,396 kVA.

9. Laboratory Building, Faculty of Agriculture

The Faculty of Agriculture Laboratory Building has two floors with a total floor area of 57 m × 16 m = 912 m ^{2}. The total electrical load power installed in the Faculty of Agriculture Laboratory Building is 68,483 kW or 71,928 kVA.

10. Faculty of Engineering Data Center Building

The Faculty of Engineering Data Center Building has two floors with a total floor area of 64 m × 19 m = 1,216 m ^{2}. The total electrical load power installed in the Data Center Building, Faculty of Engineering, is 107,799 kW or 114,647 kV.

11. Electrical Engineering Laboratory Building

The Electrical Engineering Laboratory Building has two floors with a total floor area of 68 m × 24 m = 1,632m ^{2}. The total electrical load power installed in the Electrical Engineering Laboratory Building is 168,789 kW or 187,359 kVA.

12. Electrical Engineering Lecture Building

The Electrical Engineering Lecture Building has two floors with a total floor area of 56 m × 15 m = 840 m ^{2}. The total electrical load power installed in the Electrical Engineering Laboratory Building is 37,783 kW or 40,425 kVA.

13. Civil Engineering Laboratory Building

The Civil Engineering Laboratory Building has two floors with a total floor area of 68 m × 24 m = 1,632 m ^{2}. The total electrical load power installed in the Civil Engineering Laboratory Building is 225,984 kW or 290,799 kVA.

14. Civil Engineering Lecture Building

The Civil Engineering Lecture Building has two floors with a total floor area of 56 m × 15 m = 840 m ^{2}. The total electrical load power installed in the Civil Engineering Lecture Building is 34,835 kW or 37,184 kVA.

15. Informatics and Information Systems Laboratory Building

The Informatics and Information Systems Laboratory building has two floors with a total floor area of 68 m × 24 m = 1,632 m ^{2}. The total electrical load power installed in the Informatics and Information Systems Laboratory Building is 186,339 kW or 190,543 kVA.

16. Informatics and Information Systems Lecture Building

The Informatics and Information Systems Lecture Building has two floors with a total floor area of 56 m × 15 m = 840 m ^{2}. The total electrical load power installed in the Informatics and Information Systems Lecture Building is 37,792 kW or 40,434 kVA.

17. Rusunawa Building

Rusunawa building has 7 buildings, of which 6 buildings have not yet been built and 1 other building already exists and is already functioning . The Rusunawa building has three floors with a total floor area of 38.25 m × 17.4 m = 665.55 m ^{2}. So the total electrical load power installed in the Rusunawa Building is 225.5 kW or 238,399 kVA.

Analysis of Determining the Capacity of Distribution Transformers at the Mugarsari Campus, Siliwangi University

Determining the capacity of distribution transformers is carried out by considering load characteristics, namely diversity factors and demand factors for each load. The diversity factor states that the loads do not always work synchronously, while the requirements factor states that during normal operating conditions the loads do not always work according to *the nameplate* [15].

To determine the standard needs factor value, you can see Table 1 and to determine the standard diversity factor value can be seen in Table 2 and Table 3 [16].

Table 1. Standard Need Factors

Circuit Function	*Utilization Faktor*
Lighting	1
Socket-outlets	1
Motor	0,8
Electric vehicle	1

Table 2. Diversity Factor Standards for Distribution Boards Based on IEC 61439

Type Of Load	*Assumed Loading Faktor*
Distribution – 2 and 3 circuit	0,9
Distribution – 4 and 5 circuit	0,8
Distribution – 6 and 9 circuit	0,7
Distribution – 10 or more circuit	0,6
Electric actuator	0,2
Motors ≤ 100 kW	0,8
Motor > 100 kW	1,0

Table 3. Diversity Factor Standards Based on Circuit Function (IEC 60439)

Circuit Function		*Diversity Faktor*
Lighting		1
Heating and air conditioning		1
Socket-outlets		0,1 to 0,2
10 or more		0,6
Lift and catering hoist	• *For the most powerful motor*	1
	• *For the second most powerful motor*	0,75
	• *For all motor*	0,60

Next, the distribution transformer capacity value calculation is carried out using equation 1.

$$kVA\ x\ DF\ = kVA_1\ x\ F_{D1} = kVA_2\ x\ F_{D2}\ = S\ Trafo \quad (1)$$

Where:

kVA = Electrical Power Requirements in the Building
DF = *Demand Factor* (Need Factor)
F_{D1} = Diversity Factor based on Table 3.
F_{D2} = Diversity Factor based on Table 2.
$S\ Trafo$ = Distribution Transformer Capacity

Distribution transformer capacity calculations are carried out using Ms. Excel to make the process easier. The calculations can be seen in Table 4. The calculations were carried out for each building at Mugarsari Campus, namely there are 17 buildings. Of the seventeen buildings, 7 of them have not yet been built, namely 6 Rusunawa Buildings and Multipurpose Buildings

Table 4. Calculation of Transformer Capacity

PENGGUNAAN BEBAN			DAYA SEMU (KVA)	FAKTOR KEBUTUHAN	DAYA SEMU (KVA)	FAKTOR DIVERSITAS	DAYA SEMU (KVA)	FAKTOR DIVERSITAS	DAYA SEMU (KVA)
GEDUNG REKTORAT	Lampu	562	17,185	1	17,185	1	17,185	0,9	155,267
	Kotak Kontak	140	28,000	1	28,000	0,6	16,800		
	AC	83	138,533	1	138,533	1	138,533		
GEDUNG SERBAGUNA	Lampu	1041	21,064	1	21,064	1	21,064	0,8	45,509
	Kotak Kontak	90	18,000	1	18,000	0,6	10,800		
	AC	47	15,422	1	15,422	1	15,422		
	LIFT	2	12,000	0,8	9,600	1	9,600		
MASJID MUGARSARI	Lampu	178	1,862	1	1,862	1	1,862	0,9	4,081
	Kotak Kontak	13	3,250	1	3,250	0,6	1,950		
	AC	1	0,722	1	0,722	1	0,722		
PENGGUNAAN BEBAN			**DAYA SEMU (KVA)**	**FAKTOR KEBUTUHAN**	**DAYA SEMU (KVA)**	**FAKTOR DIVERSITAS**	**DAYA SEMU (KVA)**	**FAKTOR DIVERSITAS**	**DAYA SEMU (KVA)**
GEDUNG UTAMA FAPERTA	Lampu	429	5,962	1	5,962	1	5,962	0,8	79,458
	Kotak Kontak	49	9,800	1	9,800	0,6	5,880		
	AC	38	74,022	1	74,022	1	74,022		
	LIFT	1	6,000	0,8	4,800	1	13,459		
	Pompa	2	10,824	0,8	8,659				
GEDUNG LABORATORIUM FAPERTA	Lampu	94	1,128	1	1,128	1	1,128	0,9	51,649
	Kotak Kontak	110	36,350	1	36,350	0,6	21,810		
	AC	39	34,450	1	34,450	1	34,450		
GEDUNG PERTAMINA FAPERTA	Lampu	58	0,587	1	0,587	1	0,587	0,9	9,200
	Kotak Kontak	24	4,800	1	4,800	0,6	2,88		
	AC	12	6,756	1	6,756	1	6,756		
KANTIN FAPERTA	Lampu	10	0,120	1	0,120	1	0,12	0,9	2,464
	Kotak Kontak	7	1,400	1	1,400	0,6	0,84		
	AC	2	1,778	1	1,778	1	1,778		
MASJID FAPERTA	Lampu	29	0,348	1	0,348	1	0,348	0,8	4,752
	Kotak Kontak	12	2,400	1	2,400	0,6	1,44		
	AC	2	3,800	1	3,800	1	3,8		
	Pompa	1	0,550	0,8	0,440	0,8	0,352		
SEKRETARIAT FAPERTA	Lampu	8	0,040	1	0,040	1	0,04	0,9	3,028
	Kotak Kontak	4	0,800	1	0,800	0,6	0,48		
	AC	4	3,556	1	3,556	0,8	2,844		
GEDUNG RUSUNAWA	Lampu	255	15,169	1	15,169	1	15,169	0,8	126,788
	Kotak Kontak	94	131,600	1	131,600	0,6	78,96		
	AC	2	15,867	1	15,867	1	15,867		
	Pompa	2	75,765	0,8	60,612	0,8	48,489		
GEDUNG DC FAKULTAS TEKNIK	Lampu	275	6,191	1	6,191	1	6,191	0,8	85,719
	Kotak Kontak	58	18,250	1	18,250	0,6	10,95		
	AC	21	67,656	1	67,656	1	67,656		
	Videotron	1	22,000	1	22,000	1	22		
	Pompa	1	0,550	0,8	0,440	0,8	0,352		
GEDUNG KULIAH ELEKTRO	Lampu	267	3,875	1	3,875	1	3,875	0,8	28,854
	Kotak Kontak	52	10,400	1	10,400	0,6	6,24		
	AC	23	25,600	1	25,600	1	25,6		
	Pompa	1	0,550	0,8	0,440	0,8	0,352		
GEDUNG LABORATORIUM ELEKTRO	Lampu	334	6,880	1	6,880	1	6,880	0,8	109,482
	Kotak Kontak	158	52,950	1	52,950	0,6	31,770		
	AC	36	46,067	1	46,067	1	46,067		
	Pompa	1	0,550	0,8	0,440	0,8	52,136		
	KIT TRAFO	1	4,104	0,8	3,283				
	KIT TTT	1	7,040	0,8	5,632				
	KIT PLC	1	4,104	0,8	3,283				
	KIT ELDA	1	10,944	0,8	8,755				
	KIT MME	1	10,944	0,8	8,755				
	KIT AST	4	43,776	0,8	35,021				

GEDUNG KULIAH SIPIL	Lampu	262	3,767	1	3,767	1	3,767	0,8	28,138
	Kotak Kontak	51	10,200	1	10,200	0,6	6,12		
	AC	22	24,933	1	24,933	1	24,933		
	Pompa	1	0,550	0,8	0,440	0,8	0,352		
GEDUNG LABORATORIUM SIPIL	Lampu	325	6,751	1	6,751	1	6,751	0,8	141,684
	Kotak Kontak	113	38,700	1	38,700	0,6	23,22		
	AC	16	36,111	1	36,111	1	38,911		
	Oven	2	2,800	1	2,800				
	Pompa	1	0,550	0,8	0,440	0,8	108,223		
	Chiller	1	36,188	0,8	28,951				
	Motor	1	1,584	0,8	1,267				
	Motor Condenser	1	1,364	0,8	1,091				
	Compression	1	17,000	0,8	13,600				
	Hydraulic Universal	1	17,000	0,8	13,600				
	Abrassion Machine	2	1,765	0,8	1,412				
	Hydraulic Oil	1	52,941	0,8	42,353				
	Hydraulic Vibration	1	17,000	0,8	13,600				
	Hydraulix Flexural	1	22,000	0,8	17,600				
	Concrette Mixer	1	0,294	0,8	0,235				
	Mesin Potong Gerinda	1	1,412	0,8	1,129				
GEDUNG KULIAH INFORMATIKA DAN SI	Lampu	268	3,884	1	3,884	1	3,884	0,8	28,861
	Kotak Kontak	52	10,400	1	10,400	0,6	6,24		
	AC	23	25,600	1	25,600	1	25,6		
	Pompa	1	0,550	0,8	0,440	0,8	0,352		
GEDUNG LABORATORIUM INFORMATIKA DAN SI	Lampu	397	7,671	1	7,671	1	7,671	0,8	107,124
	Kotak Kontak	338	141,100	1	141,100	0,6	84,66		
	AC	42	41,222	1	41,222	1	41,222		
	Pompa	1	0,550	0,8	0,440	0,8	0,352		
TOTAL BEBAN TERPASANG (KVA)			1.566	TOTAL KAPASITAS TRAFO UNTUK 17 GEDUNG (KVA)					1.012

Based on Table 4, the calculation of the distribution transformer capacity required for Mugarsari Campus is 1,012, so that the transformer loading is in accordance with the 2020 RUPTL standards, the transformer capacity is multiplied by 20%. So the distribution transformer capacity obtained is 1,220 kVA. The capacity available at PLN is in accordance with SPLN SPLN D3.002-1:2007, namely 1,250 kVA.

Distribution Transformer Capacity Loading Analysis at the Mugarsari Campus, Siliwangi University

Analysis was carried out to determine whether the distribution transformer loading calculation using method 1 was in accordance with the Electricity Planning Projections. Through the 2020 RUPTL, distribution transformer loading is limited from 70% to 90% to maintain the *lifetime* of the distribution transformer. To carry out a distribution transformer loading analysis, you can use the formula in equation 2 [17].

$$\%DTT = \frac{S\ (kVA)}{S\ Trafo\ (kVA)} x100 \quad (2)$$

Where:
$\%DTT$ = Total Power Used
S = Apparent Power Used
$S\ Trafo$ = Distribution Transformer Capacity

The following is the total percentage of distribution transformer loading:

$$\%DTT = \frac{S\ (kVA)}{S\ Trafo\ (kVA)} x100 = \frac{1.012\ kVA}{1.250\ kVA} x100 = 81\%$$

The distribution transformer loading percentage value is 81%, which is in accordance with the Electricity Planning Projections through the 2020 RUPTL regarding distribution transformer loading which is limited from 70% to 90%.

4. Conclusion

The total electrical power requirement is in accordance with planning data and also existing data for all buildings at the Mugarsari Campus, Siliwangi University, namely 1,566 kVA. The distribution transformer capacity calculation obtained is 1,220 kVA, in

accordance with what is available at PLN, namely 1,250 kVA. The calculated Distribution Transformer Loading is 81%, which value is still in accordance with the Electricity Planning Projections through the 2020 RUPTL.

Author contribution

Faridah Nafa Azizah: looking for calculation methods for research, collecting data, conducting field observations, planning and calculating transformer capacity using several methods. Dr. Ir. Asep Andang, S.T., M.T., IPU., Asean. Eng: Contribute in providing research titles, help search for data, supervise the research process, and provide guidance, direction, criticism and suggestions. Dr. Ir. Sutisna, S.T., M.T,: Contribute to brainstorming the knowledge needed to conduct research, supervise the research process, and provide guidance, direction, criticism and suggestions for innovations that will be carried out in the research.

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