

CAPACITY ANALYSIS OF BACKUP GENERATOR IN WORKSHOP AND LABORATORY BUILDING OF POLNAM ELECTRICAL DEPARTMENT

Vicky Salamena

Department of Electrical Engineering, Politeknik Negeri Ambon

Email : vickysalamena@gmail.com

ABSTRACT

Power electric supply to workshop and laboratorium Electrical Department in Politeknik Negeri Ambon gives by Government Electric Company (PLN). Now electric power capacity at PLN not satisfy to support demand on Ambon island, because derating of prime over (diesel engine), the engine has broken and increase of demand. Consequence of this problem is adjustment at power delivery from PLN to demand, so happen cut-off electric power to a part of demand. Impact to Electrical Department workshop and laboratorium in electric power supply not continu. For hanging this problem, make back-up power supply with added generator-set at rating needs it. This research is calculating capacity of generator-set agree with electric capacited of workshop and laboratorium Electrical Department. Total of electric capacity in kilo-volt-ampere (kVA) be obtained from accumulation of electric equipment in the workshop and laboratorium. The results of this study are to obtain protection on the main panel of 80 A, the cross-sectional area of the main panel feeder is 250 mm² and the generator capacity is 50 kVA at a phase-to-phase voltage of 380 V, AC, three-phase four wire generator type. The model or type of grounding used is TN-S.

Keywords: Electrical-instalation, Power-supply, Generator-set

INTRODUCTION

Currently, the supply of electricity on Ambon Island by the State Electricity Company (PLN) has a smaller capacity than the demand for electrical energy in the community. This is due to the ability of the prime mover (diesel engine) began to decline due to the age of use so that power-derating occurs, and also the addition of electricity customers while the generation capacity (generating station) does not increase. This resulted in adjustments to the distribution of power provided by PLN to the community. As a result of this alignment, there is a blackout or disconnection of electrical energy in rotation to each region / load concentration (load shading). Seen from the load side, the supply of electrical energy becomes discontinuous which results in problems in the operation of electrical equipment.

The Electrical Engineering Department (JTE) of Ambon State Polytechnic (Polnam) has workshops and laboratories that are used to support the teaching and learning process in this department. The workshop is a means to train students' skills to install or assemble electrical installations and electrical equipment so that the equipment is able to work properly. To run this, electrical energy is needed in order to operate the equipment and its installation. Likewise, in the laboratory there is testing and measurement equipment that can only be operated if there is a source of electricity. Thus a continuous source of electrical energy is an important component in organizing the teaching and learning process in JTE workshops and laboratories.

As a result of the supply of electrical energy sourced from PLN which sometimes experiences blackouts when the energy is needed during the teaching and learning process in the workshop and laboratory, it is necessary to have another energy source that can support these activities. The existing backup energy source at Polnam has a small capacity and can only supply lighting and air conditioning loads in some buildings. In this study it is proposed to organize an auxiliary or backup supply that comes from a generator-set with electrical power (capacity) in

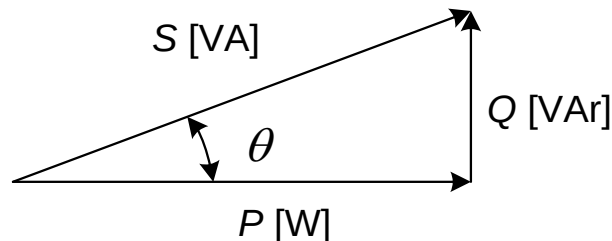
accordance with the needs of JTE workshops and laboratories. Likewise, planning the installation system for input feeders from PLN and generator-set to the main panel in the workshop/laboratory of JTE.

The problem studied in this research is how to get the capacity of generator-sets that function as a backup supply to supply electrical power needs in JTE workshops and laboratories. By referring to the nominal power of the load installed in each sub panel, namely lighting loads and power loads (workshop and laboratory equipment), the required power is the accumulation of the fixed load of each building, room and existing practical and practicum equipment. This study aims to obtain the rating (capacity in kVA) of the generator-set in accordance with the needs of JTE workshops and laboratories, and design a circuit of reinforcement from PLN and generator-set to the main panel of JTE workshops and laboratories.

LITERATURE REVIEW

Alternating Current Power

Alternating current (AC) power is the multiplication of voltage and current. The presence of resistive and reactive loads creates a phase difference between voltage and current. Resistive loads will absorb active (real) power and reactive loads (inductance and capacitance) absorb reactive power, these two powers that cause the power angle, namely the angle between active power and apparent power (power multiplication between voltage and current). The power factor is the ratio between active power P and apparent power S . The phasors of these three powers are depicted in a triangle called the power triangle. The power triangle is shown in Figure 4.



Gambar 4. Segitiga daya AC

Mathematically expressed in complex numbers as shown in equation.

Apparent power: $S = V \cdot I^* \text{ [VA]}$,

Active power: $P = S \cos \theta \text{ [W]}$

Reactive power: $Q = S \sin \theta \text{ [VAr]}$.

Power factor is the ratio between active power and apparent power, expressed by equation.

$\cos \theta = P/S \text{ (2)}$

The magnitude of the power angle is:

$\angle \theta = \cos^{-1} \left[\frac{P}{S} \right] \text{ , (3)}$

According to the relationship in Figure 4, the Pythagorean postulate can be stated that:

$S = \sqrt{P^2 + Q^2} \text{ (4)}$

Thus, by knowing the two power variables or the power angle, other power components can be found.

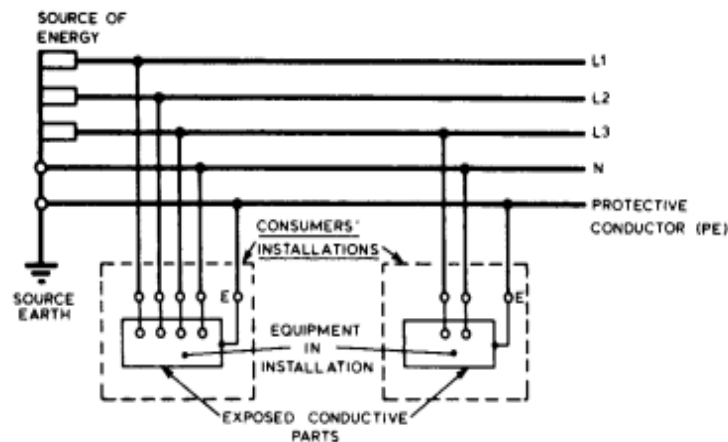
Grounding System[2]

Electrical installation is a system that can distribute electrical energy from a source of electrical energy to any load attached to the source. In a building the source of electrical energy can be expressed as a main panel where electrical energy is entered into the main panel from a network outside the building, then this energy is channeled through this panel to each load attached to the panel through a wiring network. So the installation system

consists of the source / main panel, the installation network and the load attached to it. In the panel there are safety devices (circuits breakers, fuses, etc.), bus bars (divider rails) and are also equipped with metering devices (voltmeters, amperimeters, frequencymeters, etc.). While the installation network is a cable (insulated conductor wire) whose capacity is in accordance with the current and voltage required by the load, then the type of cable is determined by the placement location or place where the cable is installed (in the open air, in the ground or inside the building / indoor). The supply system depends on the characteristics of the place and the electrical load, this is required by the Institution of Electrical Engineers, IEE is divided into several types, namely:

TN-S system

This system has a neutral point from the energy source directly connected to the ground (earth). Output from the panel for protection and supply there are phase conductors (L1, L2, L3), Neutral conductor (N) and grounding conductor or protecting earth (PE). It is a five-conductor system with each conducting equipment body connected to a grounding wire connected at the source panel. This system is shown in Figure 1.



This system does not have a grounding wire, which is a four-wire system consisting of three phase conductors and one neutral conductor. Grounding is carried out on each metal-clad equipment / load directly to the ground. This system is shown in Figure 3.

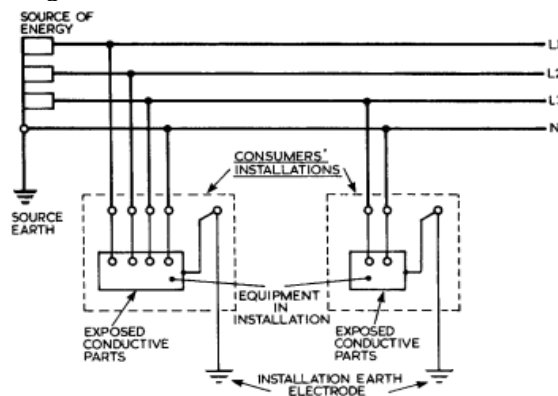


Figure 3 TT supply system

From IEE rule 433-20-20, the current that a conducting wire can deliver based on the nominal current of

the load on a continuous basis is: $I_{\text{wire}} = I_{\text{"nominal"}/0.725}$ (5), Cable Characteristics[3]

Conductors for three-phase systems are usually identified by color coding for all guaranteed balanced loads in accordance with the phase sequence, especially for induction motors. Colors are used following the International Standard, IEC 60446. Color codes for some countries are shown in Table 1.

Table 1 Color of connecting cables for three-phase systems

Country	L1	L2	L3	Neutral	Ground / protective earth
Australia and New Zealand as per AS/NZS 3000:2007 Figure 3.2 (or as per IEC 60446 as approved by AS:3000)	Red (or brown)	White (or black) (prev. yellow)	Dark blue (or grey)	Black (or blue)	Green/yellow striped (green on very old installations)
Canada (mandatory)	Red	Black	Blue	White or Grey	Green or bare copper
Canada (isolated three-phase installations)	Orange	Brown	Yellow	White	Green
European Union and all countries who use European CENELEC standards April 2004 (IEC 60446), Hong Kong from July 2007, Singapore from March 2009	Brown	Black	Grey	Blue	Green/yellow striped
Older European (IEC 60446 , varies by country)	Red	Yellow	Blue	Black	Green/yellow striped (green on installations before c. 1970)
UK until April 2006, Hong Kong until April 2009, South Africa, Malaysia, Singapore until February 2011	Red	Yellow	Blue	Black	Green/yellow striped (green on installations before c. 1970)
India and Pakistan	Red	Yellow	Blue	Black	Green/yellow striped, or green
Former USSR (Russia, Ukraine, Kazakhstan) and People's Republic of China (per GB 50303-2002 Section 15.2.2)	Yellow	Green	Red	Sky blue	Green/yellow striped
Norway	Black	White/Grey	Brown	Blue	Yellow/green striped, older may be only yellow or bare copper
United States (common practice)	Black	Red	Blue	White, or grey	Green, green/yellow striped or a bare copper wire
United States (alternative practice) ^[note 6]	Brown	Orange (delta), violet (wye)	Yellow	Grey, or white	Green

METHODS

The research was conducted by taking load data located in the Workshop Building of the Electrical Engineering Department. The load parameters are the active power of the equipment and its power factor. From these two parameters,

reactive power is calculated for simulation purposes using the Matlab program. Simulation in the Matlab program is carried out by defining the equipment in each laboratory and workshop as a bulk load on each panel sub unit with a certain amount of power and work factor described in Table 2 [4].

Table 2 Load power values of each panel sub unit

NO.	UNIT PANEL	POWER (watt)	POWER FACTORS
1	Power Workshop Room	8.000	0,8
2	Mechanical Workshop Room	5.000	0,8
3	Refrigeration Workshop Room	3.000	0,7
4	M&R Workshop Room	4.000	0,6
5	Electrical Machinery Laboratory Room	8.000	0,8
6	Electrical Installation Laboratory Room	2.000	0,7
7	El. Power	2.000	0,6
8	Main Panel	32.000	-

From the data in Table 1, the reactive power value is calculated using equation (3), the results of the reactive power calculation are shown in Table 3, as follows,

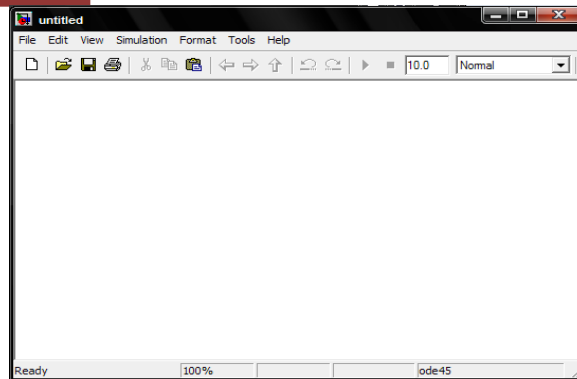
Table 3 Active, reactive and power factor values

NO.	UNIT PANEL	P (watt)	P.F.	Q (Var)
1	Power Workshop Room	8.000	0,8	6.000
2	Mechanical Workshop Room	5.000	0,8	3.750
3	Refrigeration Workshop Room	3.000	0,7	3.060
4	M&R Workshop Room	4.000	0,6	5.320
5	Electrical Machine Lab Room	8.000	0,8	6.000
6	Electrical Installation Lab Room	2.000	0,7	2.040
7	El. Power	2.000	0,6	2.660
8	Main Panel	32.000		28.830

RESULTS AND DISCUSSION

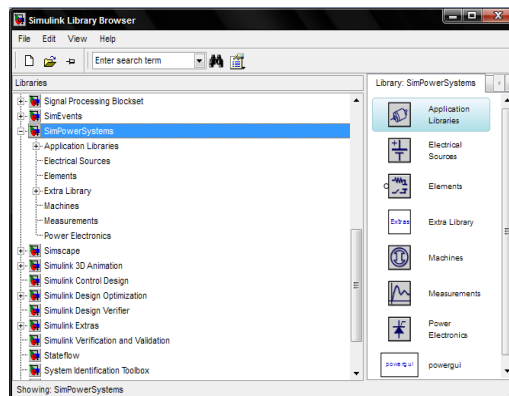
Matlab Simulink Programming [5]

The facility used from the Matlab program is Simulink to create an electrical installation circuit in the Ambon State Polytechnic Electrical Engineering Department Workshop building, then to display the results using the 'powergui' block. The steps to operate the Matlab program can be described as follows, activate the Matlab program through the icon on the desktop or take it in the start menu of the Window operating system. After that, take the simulink window in the tool bar of the Matlab program window. The result is a window display like Figure 5.



Simulink window display

After opening the Simulink window then take the 'Simulink Library' window which contains components related to the installation system to be simulated. These components are found in 'SimPowerSystem'. The Simulink-Library window view is shown in Figure 6.



Simulink-library window display

Next, take all the necessary components from the Simulink-library window and place them in the simulink window and assemble them according to the simulation circuit. After assembling each component, the parameters are set. The components used are:

1. Three-phase AC source

Its setup window is shown in Figure 7.

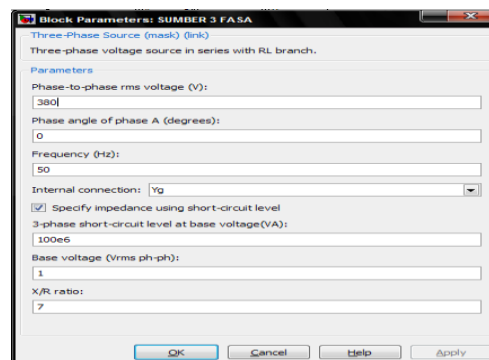


Figure 7: Three-phase ac source parameter setting window

What is set is the value of the source voltage (line to line), frequency and phase winding relationship of the source. Likewise, the system base for per unit or actual values.

1. Circuit-breaker (CB)

The display of the CB parameter setting window is shown in Figure 8.

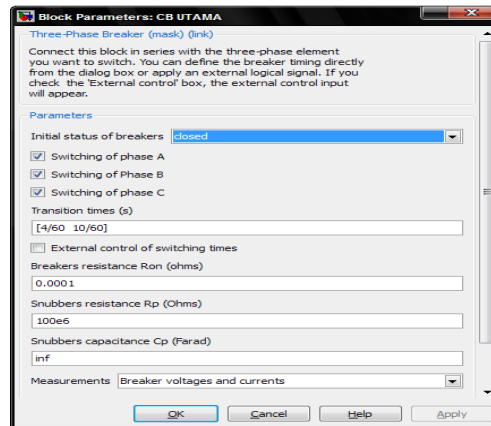
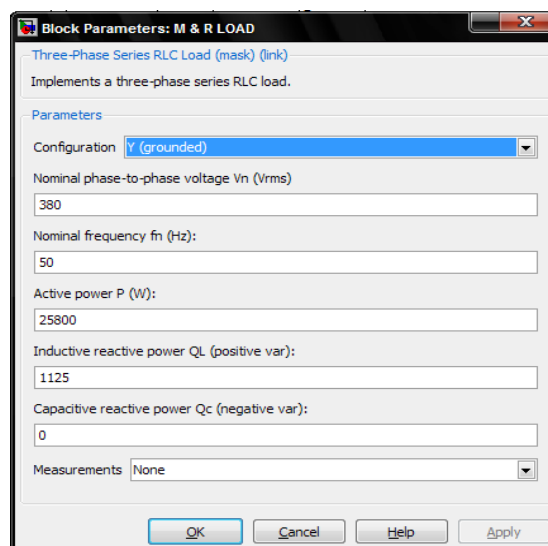


Figure 8. CB parameter setting window display

The parameter set is to open or close the CB contacts and activate them for phases A, B and C.

1. Three-phase load

To simulate the load on the installation system, a three-phase series RLC load component is used in the simulink-library. The display window for setting its parameters is shown in Figure 9.



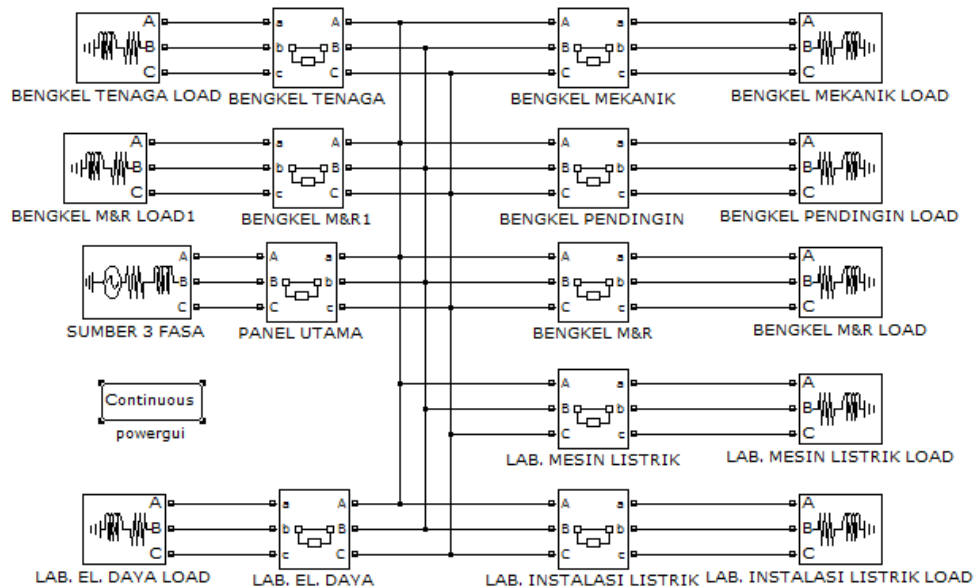
Display window of three-phase series RLC load settings

What is set in this load component is the working voltage, frequency, active power and reactive power (L

or C). After all the components are assembled and the parameters are set, then a simulation is carried out by running the program. The load at each location is set on the load component in the simulation circuit. From the existing load data, the real power can be entered directly into the load component parameter window.

Calculation of Safety Rated Current

The result of the simulation is the amount of current in each branch of the circuit, starting from the sub panel in each workshop and laboratory room and the main panel as the supply panel. The results displayed are the steady-state of the current which will be used to determine the wire cross section and the CB rating on the main panel as well as the separation switch between PLN and the s-generator. Other simulation results that can be displayed are the voltage and current at each CB, the source voltage (phase to neutral voltage) and the peak value of each variable (current and voltage). What is shown in this simulation is the rms current in each branch of the circuit. The circuit to simulate the installation system in the JTE Workshop/Laboratory building is shown in Figure 10.



Simulation of the installation network of the TE Department Workshop building

9.49 Arms	-36.85°	----	I1_phase_A:	BENGKEL MEKANIK LOAD
9.49 Arms	-156.85°	----	I1_phase_B:	BENGKEL MEKANIK LOAD
9.49 Arms	83.15°	----	I1_phase_C:	BENGKEL MEKANIK LOAD
6.51 Arms	-45.55°	----	I1_phase_A:	BENGKEL PENDINGIN LOAD
6.51 Arms	-165.55°	----	I1_phase_B:	BENGKEL PENDINGIN LOAD
6.51 Arms	74.45°	----	I1_phase_C:	BENGKEL PENDINGIN LOAD
15.19 Arms	-36.85°	----	I1_phase_A:	BENGKEL TENAGA LOAD
15.19 Arms	-156.85°	----	I1_phase_B:	BENGKEL TENAGA LOAD
15.19 Arms	83.15°	----	I1_phase_C:	BENGKEL TENAGA LOAD
10.11 Arms	-53.05°	----	I1_phase_A:	BENGKEL M&R LOAD1
10.11 Arms	-173.05°	----	I1_phase_B:	BENGKEL M&R LOAD1
10.11 Arms	66.95°	----	I1_phase_C:	BENGKEL M&R LOAD1
5.06 Arms	-53.05°	----	I1_phase_A:	LAB. EL. DAYA LOAD
5.06 Arms	-173.05°	----	I1_phase_B:	LAB. EL. DAYA LOAD
5.06 Arms	66.95°	----	I1_phase_C:	LAB. EL. DAYA LOAD
4.34 Arms	-45.55°	----	I1_phase_A:	LAB. INSTALASI LISTRIK LOAD
4.34 Arms	-165.55°	----	I1_phase_B:	LAB. INSTALASI LISTRIK LOAD
4.34 Arms	74.45°	----	I1_phase_C:	LAB. INSTALASI LISTRIK LOAD
15.19 Arms	-36.85°	----	I1_phase_A:	LAB. MESIN LISTRIK LOAD
15.19 Arms	-156.85°	----	I1_phase_B:	LAB. MESIN LISTRIK LOAD
15.19 Arms	83.15°	----	I1_phase_C:	LAB. MESIN LISTRIK LOAD
75.37 Arms	-43.47°	----	I1_phase_A:	SUMBER 3 FASA
75.37 Arms	-163.47°	----	I1_phase_B:	SUMBER 3 FASA
75.37 Arms	76.53°	----	I1_phase_C:	SUMBER 3 FASA

Figure 11. Simulation results of the Electrical Workshop building installation

From the simulation results, the current flowing in each sub panel is shown in Table 4.

Table 4 Current in each sub panel and main panel

NO.	UNIT PANEL	P (watt)	P.F.	Q (Var)	Arus (A)
1	Power Workshop Room	8.000	0,8	6.000	15,19
2	Mechanical Workshop Room	5.000	0,8	3.750	9,49
3	Refrigeration Workshop Room	3.000	0,7	3.060	6,51
4	M&R Workshop Room	4.000	0,6	5.320	10,11
5	Electrical Machine Lab Room	8.000	0,8	6.000	15,19
6	Electrical Installation Lab Room	2.000	0,7	2.040	4,34
7	El. Power	2.000	0,6	2.660	5,06
8	Main Panel	32.000		28.830	75,37

The current-carrying capacity of the conductor wire () is calculated by equation (1), while to calculate the cross-sectional area of the conductor wire for a three-phase system can be done by equation:

$$A = (\sqrt{3} \cdot I \cdot L \cdot \cos\phi) / (\gamma \cdot u)$$

with:

- : load current [A],
- : conductor length [m],
- : load power factor,
- : copper type conductor [ohm meter],
- : voltage loss (2 volts) [V].

The calculation results for the TE department workshop building are shown in Table 5.

Table 5 Calculation results of wire current and conductor cross section

NO.	UNIT PANEL	I_n (A)	I_k (A)	I_{CB} (A)	A (mm ²)
1	Power Workshop Room	15,19	20,95	16	9,06
2	Mechanical Workshop Room	9,49	13,09	10	0,32
3	Refrigeration Workshop Room	6,51	8,98	6	3,88
4	M&R Workshop Room	10,11	13,94	10	5,82
5	Electrical Machine Lab Room	15,19	20,95	16	12,95
6	Electrical Installation Lab Room	4,34	5,99	6	1,94
7	El. Power	5,06	6,98	6	2,59
8	Main Panel	75,37	103,96	80	237,66

By adjusting the value of the nominal current simulation results and the results of the calculation of the conductor wire cross-section with the fabrication standard value, the CB rating value and the wire cross-section value used are shown in Table 6.

Table 6 CB rating values and wire cross sections used

NO.	UNIT PANEL	I_n (A)	I_k (A)	I_{CB} (A)	A (mm ²)
1	Power Workshop Room	15,19	20,95	16	10,00
2	Mechanical Workshop Room	9,49	13,09	10	2,50
3	Refrigeration Workshop Room	6,51	8,98	6	4,00
4	M&R Workshop Room	10,11	13,94	10	6,00
5	Electrical Machine Lab Room	15,19	20,95	16	16,00
6	Electrical Installation Lab Room	4,34	5,99	6	2,50
7	El. Power	5,06	6,98	6	4,00
8	Main Panel	75,37	103,96	80	250,00

Based on the results shown in Table 6, a one-line diagram can be drawn for the extension to the main panel of the JTE workshop/laboratory as shown in Figure 12.

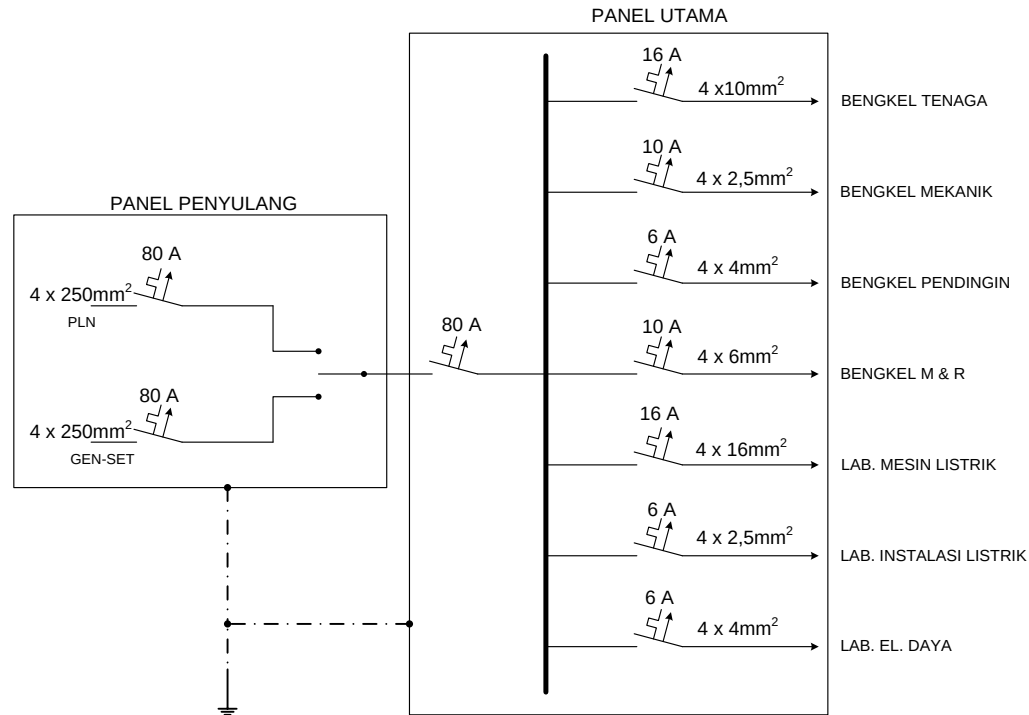


Figure 12: JTE workshop/laboratory main panel feeder

The repeater panel is added before entering the main panel of the JTE workshop/laboratory. After passing through each CB (PLN and Gen-set), the supply is connected to the PLN or Gen-set selector switch, then entered into the main panel master CB and then distributed through each safety in each sub-unit panel. The CB current value for PLN and Gen-set is equalized with the main panel CB value as well as the wire cross section. The conductivity of the selector switch is equalized with the current conductivity of the main panel circuit wire. Taking into account the large supply of reserve value when the Generator-set is working as well as the capacity in the market, the capacity of the Generator-set is selected 50 kVA with a generator power factor of 0.8 lagging.

Determination of Grounding System

The grounding system is determined based on the load spread in each workshop and laboratory room. The grounding electrode is connected directly to the main panel (Figure 4) and uses the TN-S system, namely the neutral conductor (N) and the earthing conductor (protecting Eart, PE) installed separately to each sub-panel in each room.

CONCLUSION

From the results of the discussion it can be concluded that: (1) The simulation results using the matlab program obtained the main panel current of 75.37 A, so the main safety 80 A is used, (2) The cross section of the wire from PLN and Generator-set to the main panel, amounting to 250 mm², (3) Generator-set capacity is obtained at 50 kVA, with a generator work factor of 0.8 lagging, (4) The type of grounding used is TN-S.

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