4 ELECTRICAL LOAD

The electrical load is any device, equipment, or system that consumes electrical energy when connected to an electrical supply, representing the demand placed on an electrical system.

4.1 INDIVIDUAL LOAD

– The electrical demand of a single device or piece of equipment, usually based on its rated power or manufacturer rating (nameplate).
– May be expressed in watts (W) or volt-amperes (VA) depending on whether the load is based on actual equipment ratings or standard allowance values.

Table 1 Typical Individual Electrical Loads

Load Device	Typical Load per Unit
Lighting Outlet	100W
Ceiling Fan	60W - 100W
Convenience Outlet (CO)	180W
Television	80W - 400W
Sound System	100W - 1,000W
Small Appliance Outlet (SAO)	180W
Server / Networking Equipment	500W - 2,000W
Computer / Workstation	300W - 600W
Bathroom Outlet	600W
Air Conditioning	1 HP = 746 W (≈ 1 kVA)
Water Heater	4,000W
Electric Stove	1,500W - 3,500W
Washing Machine	500W - 1,500W
Dryer	1,500W - 5,000W
Refrigerator	100W - 800W
Microwave Oven	600W - 1,200W
Dishwasher	1,200W - 1,500W
Security System (CCTV, Alarm)	50W - 500W
Pump (Water Supply / Fire Protection)	2,000W - 10,000W
Elevator (if applicable)	5,000W - 10,000W

**Electrical loads shown are typical values used for preliminary load estimation and academic design purposes only. Final load calculations shall be based on actual equipment nameplate ratings, demand factors, and applicable provisions of the Philippine Electrical Code (PEC).*

4.2 CIRCUIT LOAD

– The circuit load is the total electrical demand of all individual loads connected to a single branch circuit, expressed in watts (W) or volt-amperes (VA).
– It is used to determine the required circuit breaker rating, conductor size, and safe operating current of the circuit.

4.2.1 Average Grouping of Circuits

General Circuits

Used for normal, low-to-moderate demand loads.

Table 2 Average Grouping of General Circuits

Circuit Type	Typical Quantity per Circuit
Lighting Circuit	10–15 fixtures
Convenience Outlets (CO)	8–10 outlets

Special-Purpose Circuits

Used for loads with higher demand or special location requirements.

Table 3 Average Grouping of Special-Purpose Circuits

Circuit Type	Typical Quantity per Circuit
Small Appliance Outlets (SAO)	2–4 outlets
Kitchen Outlets	2–3 outlets
Bathroom Outlets (GFCI)	1–2 outlets
Outdoor Outlets (GFCI & weatherproof)	1–2 outlets

Dedicated Circuits

– Used for single equipment or appliances that require an exclusive circuit.
– One major appliance = one dedicated circuit

Table 4 Average Grouping of Dedicated Circuits

Circuit Type	Typical Quantity per Circuit
Refrigerator outlet	1 per circuit
Microwave outlet	1 per circuit
Dishwasher outlet	1 per circuit
Electric range / stove	1 per circuit
Water heater	1 per circuit
Air-conditioning unit	1 per circuit
Washing Machine	1 per circuit
Dryer	1 per circuit
Pump (water / fire)	1 per circuit
Elevator	1 per circuit

Critical Circuits

– Used for life-safety, essential, or continuous-operation systems that must remain operational during emergencies.
– These are often on separate panels and are connected to generator / UPS / battery backup.

Table 5 Average Grouping of Critical Circuits

Circuit Type	Typical Quantity per Circuit
Emergency lighting	Separate life-safety circuit
Exit signs	With emergency lighting or separate circuit
Fire alarm system	Dedicated circuit
Server / IT equipment	1–2 outlets (dedicated)
Communication systems	Dedicated circuit
Smoke control / pressurization	Dedicated circuit

4.2.2 Continuous Load

– A continuous load is an electrical load that is expected to operate for three (3) hours or more without interruption.
– For circuits supplying continuous loads, the *rated capacity of the circuit breaker and conductors shall not be loaded beyond 80%* of their rating.
– Equivalently, the circuit breaker must be sized at 125% of the continuous load.

Commonly Continuous Loads *(Operate 3 hours or more)*

- Lighting Circuit
- Emergency lighting
- Exit signs
- Fire alarm system
- Server / IT equipment
- Communication systems
- Smoke control
- Pressurization systems

Conditional Continuous Loads *(Depends on usage and design intent)*

- Refrigerator outlet
- Air-conditioning unit
- Pump (water supply)
- Outdoor lighting

In practice, it is best to consider conditionally continuous loads as continuous unless stated otherwise.

4.2.3 Circuit Load Calculation

Formula:

$$VA = Quantity_{Load\ Device} \times Individual\ Load$$

$$VA_{Continuous} = \frac{VA}{0.80}$$

VA = Circuit Load (Volt-Amperes)
$Quantity_{Load\ Device}$ = Quantity of the load device grouped in the circuit
$Individual\ Load$ = Electrical demand of a single load device (W)
$VA_{Continuous}$ = Continuous Load

Example:

Determine the total circuit load for Circuit 1 – Lighting Outlet.
Given:
– 10 Lighting Fixtures

Solution:

$$\begin{aligned}\text{VA} &= \text{Quantity}_{\text{Load Device}} \times \text{Individual Load}\\ &= 10\text{ units} \times 100\text{W}\\ \textbf{VA} &= \textbf{1,000W}\\ \text{VA}_{\text{Continuous}} &= \frac{\text{VA}}{0.80}\\ \text{VA}_{\text{Continuous}} &= \frac{1{,}000\text{W}}{0.80}\\ \textbf{VA}_{\textbf{Continuous}} &= \textbf{1,250W}\end{aligned}$$

4.3 VOLTAGE

The electrical potential difference between two points in a circuit that drives electric current through a conductor.

4.3.1 Single-Phase Voltage (1Ø, 230V)

– There is only one phase
– The phase current = circuit current

Single-Phase, Line-to-Neutral (L–N)

– The load is connected between one line conductor and the neutral.
– Common for:
  – General circuits (lighting, convenience outlets)
  – Some special-purpose circuits with modest power demand

Single-Phase, Line-to-Line (L–L)

– The load is connected between two phase conductors.
– Commonly used for higher-power single-phase dedicated loads.

4.3.2 Three-Phase Voltage (3Ø, 400V)

– The total load is shared by three phases
– Three-phase carries more power with less current, uses smaller conductors and has lower voltage drop.

Rule of Thumb:

- For ≤ ~10kVA (10,000VA), single-phase is usually sufficient
- For > ~10–15kVA (10,000-15,000VA), three-phase is preferred

Loads that typically require 3-Phase:

- Large air-conditioning units
- Large pumps
- Motors
- Elevators
- Smoke control
- Pressurization fans
- Industrial machinery

Three-Phase (L1–L2–L3)

– A three-phase load connected across all three phases without neutral.
– Voltage between any two phases is 400V.

Three-Phase, Four-Wire (L1–L2–L3–N)

– A three-phase load with neutral, allowing both 400V and 230V loads.
– Supplies both:
  – Three-phase loads at 400V between phases (L–L)
  – Single-phase loads from the same system at 230V between any phase and neutral (L–N)

4.4 CURRENT PHASE RATING

– The amount of electrical current carried by each phase of an electrical system under a given load condition.
– It indicates how much current flows per phase conductor.

4.4.1 Single-Phase Current Phase Rating

The amount of electrical current carried by each phase of a single-phase electrical system.

Formula:

$$I_{Phase} = \frac{VA}{V_{Line}}$$

I_{Phase} = *Current Phase Rating*
VA = *Circuit Load (Volt-Amperes)*
V_{Line} = *Line Voltage*

Example:

Determine the current phase rating of Circuit 1 – Lighting Outlet supplied at 230V.
Given:
– Circuit 1 – Lighting Outlet total Circuit Load = 1,250W (1,250VA)

Solution:

$$\begin{aligned}\text{I}_{\text{Phase}} &= \frac{\text{VA}}{\text{V}_{\text{Line}}}\\ &= \frac{1{,}250\text{VA}}{230\text{V}}\\ \textbf{I}_{\textbf{Phase}} &= \textbf{5.43A}\end{aligned}$$

4.4.2 Three-Phase System Current Phase Rating

The amount of electrical current carried by each phase of a three-phase electrical system.

Formula:

$$I_{3Phase} = \frac{VA}{\sqrt{3} \times V_{Line}}$$

I_{3Phase} = *Current Three-Phase Rating*
VA = *Circuit Load (Volt-Amperes)*
V_{Line} = *Line Voltage*

Example:

Determine the current phase rating of Circuit 10 – Elevator supplied at 400V.
Given:
– Circuit 10 – Elevator Circuit Load = 10,000W (10,000VA)

Solution:

$$\begin{aligned}\text{I}_{\text{3Phase}} &= \frac{\text{VA}}{\sqrt{3} \times \text{V}_{\text{Line}}}\\ &= \frac{10{,}000\text{VA}}{\sqrt{3} \times 400\text{V}}\\ \textbf{I}_{\textbf{3Phase}} &= \textbf{14.43A}\end{aligned}$$

4.5 OVERCURRENT PROTECTION

– The provision of devices that interrupt electrical current when it exceeds safe limits to protect conductors, equipment, and occupants.
– It shall be rated to protect the conductor and equipment without exceeding their allowable ampacity.

4.5.1 Ampere Trip (AT)

– The rated current at which a circuit breaker is designed to trip and interrupt the circuit during overcurrent conditions.
– It must be greater than the load current.
– It defines the breaker size used in computation and scheduling.

Table 6 Ampere Trip Rating

Calculated Current (A)	Standard AT (Breaker Size)
≤ 12 A	15 AT
12.1 – 16 A	20 AT
16.1 – 24 A	30 AT
24.1 – 32 A	40 AT
32.1 – 40 A	50 AT
40.1 – 48 A	60 AT
48.1 – 64 A	80 AT
64.1 – 80 A	100 AT
80.1 – 100 A	125 AT
100.1 – 120 A	150 AT
120.1 – 160 A	175 AT
160.1 – 200 A	200 AT

4.5.2 Circuit Breaker Pole (Pole)

– Each pole of a circuit breaker is connected to one energized conductor. When a breaker trips, all poles open at the same time, ensuring safe disconnection of the circuit.
– The number of poles of a circuit breaker is determined by the voltage level and phase of the load.

Table 7 Circuit Breaker Pole

Breaker Type	Conductors Disconnected	Typical Voltage
1-Pole	1 phase	230V (L–N)
2-Pole	2 phases	230V (L–L)
3-Pole	3 phases	400V (L1–L2–L3)
4-Pole	3 phases + neutral	400V (L1–L2–L3-N)

4.5.3 Circuit Breaker

Protects electrical circuits by automatically disconnecting power when unsafe current conditions occur.

Typical Practice in Circuit Breaker Selection

- Circuit breakers are sized above the calculated load current to provide a safety margin.
- The calculated current is the primary basis for breaker selection.
- For continuous loads (≥ 3 hours), breakers are sized at 125% of the load (80% rule).
- When load current is near a standard rating, the next higher breaker size is selected.
- 20 A breakers are commonly used for lighting and outlet circuits; 15 A breakers are rarely used in practice.
- Voltage and phase determine the number of poles, not the breaker ampere rating.
- Motor loads may require larger breakers due to starting current and manufacturer requirements.
- Future allowance is provided by including spare circuits (2–3 spares).
- Final breaker and conductor sizing must comply with code and equipment nameplate ratings.

Example:

Determine the overcurrent protection for the following circuits:
– Circuit 1 – Lighting Outlet supplied at 230V
– Circuit 6 – Refrigerator Outlet supplied at 230V
– Circuit 10 – Elevator supplied at 400V
Given:
– Circuit 1 – Lighting Outlet Current Phase Rating = 5.43A
– Circuit 6 – Refrigerator Outlet Current Phase Rating = 2.17A
– Circuit 10 – Elevator Current Phase Rating = 14.43A

Answer:

– Use 1-Pole 20A Circuit Breaker for Circuit 1 – Lighting Outlet;
– Use 2-Pole 20A Circuit Breaker for Circuit 6 – Refrigerator Outlet; and
– Use 3-Pole 30A Circuit Breaker for Circuit 10 – Elevator Current.

Although the calculated current is low, elevator circuits commonly use larger breakers to account for motor starting current and manufacturer requirements.

4.6 CONDUCTORS & CONDUITS

4.6.1 Conductors

Conductors are insulated wires that carry electrical current from the source to the load.

Quantity of Conductors

– Panel schedules list current-carrying conductors only.
– Equipment grounding conductors are required but are not included in the quantity count.
– Neutral conductors are counted only if they carry current.

Table 8 Quantity of Conductors Typical Practice

Voltage	Quantity of Conductors
1Ø, 230 V (L–N)	2 conductors (phase + neutral)
1Ø, 230 V (L–L)	2 conductors (two phases)
3Ø, 400 V (no neutral)	3 conductors (three phases)
3Ø, 400 V (with neutral)	4 conductors (three phases + neutral)

Equipment grounding conductors are required but are not included in the conductor count.

Conductor Size

– Conductor size is determined by the circuit breaker ampere trip (AT).
– The conductor ampacity must be equal to or greater than the breaker rating.

Table 9 Circuit Breaker Ampere Rating and Typical Equivalent Conductor Sizes

Ampere Rating	Conductor Size
15 A	2.0 mm^2
20 A	3.5 mm^2
30 A	5.5 mm^2
40 A	8.0 mm^2
50 A	14 mm^2
60 A	22 mm^2
70 A	30 mm^2
80 A	30 mm^2
90 A	38 mm^2
100 A	38 mm^2
125 A	50 mm^2
150 A	60 mm^2
175 A	80 mm^2

Conductor Type

Copper conductors are the default and preferred material for building electrical installations.

Table 10 Common Applications of Different Types of Conductors

Conductor Type	Typical Applications
TH	Indoor dry locations; conduit wiring (older installations)
TW	Indoor wet locations; conduit wiring (older installations)
THW	Indoor wet and dry locations; conduit wiring
NM / NM-B (Romex)	Indoor dry locations; residential concealed wiring; not for wet areas
BX / AC (Armored Cable)	Indoor dry locations; exposed wiring with mechanical protection
THHN	General-purpose conduit wiring; dry and damp locations
THWN / THHN-THWN-2	Indoor and outdoor conduit wiring; wet and dry locations
THHX	High-temperature indoor applications; industrial use
XHHW	Feeders, service entrance, underground and high-power distribution
Busbars	Large power distribution; substations and industrial systems
Cable Bus	Large industrial plants; long-distance, high-capacity distribution

Considerations:

- NMC, BX
  – Used without conduits in residential & commercial indoor settings.
- THHN, THWN
  – *Most commonly used* for feeders and branch circuits inside conduits.
- XHHW
  – High-temperature, and moisture-resistant wire for high-voltage applications.
- Busbars, Cable Bus
  – Used in industrial plants, substations, and long-distance high-current distribution.

4.6.2 Conduits

Protective raceways used to route and protect conductors.

Conduit Size (Ø)

– Determined by the number and size of conductors.
– Conduit fill should not exceed 40% of the internal area.

Table 11 Typical Conductor Sizing Practice

Nominal Size (mm)	Typical Use
15mm, 20mm, 25mm	branch-circuit conductors
32mm, 40mm, 50mm, 65mm, 80mm, 100mm	feeders, panel mains, service entrance, main service raceways

Conduit Type

The type of conduit used is typically based on installation location, environmental conditions, and required mechanical protection.

Table 12 Application of Different Types of Conductors and Conduits in Various Scenarios

Scenario	Conductor	Conduit
Underground Wiring (buried cables, street lighting)	THWN, THWN-2, XHHW	Required (PVC Sch. 40/80, IMC, RSC)
Embedded in Concrete Walls / Slabs	THHN/THWN, THWN-2	Required (PVC rigid conduit, IMC, RSC)
Concealed in Ceiling Spaces (offices, commercial)	THHN, THWN	Required (EMT, flexible conduit, PVC)
Surface-Mounted on Walls (industrial, garages)	THHN, THWN	Required (EMT, IMC, RSC, PVC rigid)
Wet and Damp Locations (bathrooms, kitchens, outdoors)	THWN, THWN-2, XHHW	Required (PVC, IMC, RSC)
Above Drop Ceilings (Non-Plenum)	NM, AC, or THHN in raceway	Raceway required for THHN/THWN
Inside Panel Boards & Junction Boxes	THHN, THWN	Conduit required up to enclosure
Exposed Outdoor Wiring (rooftops, solar)	THWN-2, XHHW	Required (PVC Sch. 80, IMC, RSC)
Hazardous Locations	XHHW, THWN-2	Required (RSC with sealing fittings)
Temporary Installations (construction, events)	SOOW, portable cords	Not required (portable use only)
Interior Dry Partitions (residential)	NM (Romex), BX / AC	Not required
Large Power Distribution	Busbar (enclosed busway)	Not required
Large Power / Long Distance	Cable Bus	Not required

Considerations:

- Rigid Non-Metallic Conduit (PVC Pipe)
  - Permanent, concealed installations requiring protection
  - Embedded in concrete, underground wiring, straight raceway runs
- Flexible Non-Metallic Conduit (ENT)
  - Short runs and flexible connections
  - Lighting fixtures, equipment connections, tight spaces (indoor only)
- Surface Raceway (PVC Moulding)
  - Exposed surface wiring
  - Retrofit and renovation installations
- Electrical Metallic Tubing (EMT)
  - Exposed indoor installations
  - Commercial and institutional buildings requiring moderate protection
- Rigid Steel Conduit (RSC) / Intermediate Metal Conduit (IMC)
  - Outdoor and industrial applications
  - Service entrances, heavy-duty and high-impact areas

4.7 PANEL LOAD

The sum of circuit loads served by a panel; it may be expressed as connected load or demand load.

4.7.1 Connected Load

The total electrical load connected to a panel board before applying demand factors which represents the maximum possible load if all circuits operate simultaneously.

Formula:

$$VA_{Connected} = \Sigma \text{ All Circuit Loads}$$

$VA_{Connected}$ = Connected Load

Example:

Determine the connected load of the panel board based on the load schedule below.

Circuit	Description	Circuit Load (VA)
1	Lighting Circuit	1,500VA
2	Convenience Outlets	3,240VA
3	Small Appliance Outlets	1,800VA
4	Refrigerator Outlet	800VA
5	Microwave Outlet	1,200VA

Solution:

$$\begin{aligned} VA_{Connected} &= \Sigma \text{ All Circuit Loads} \\ &= 1{,}500VA + 3{,}240VA + 1{,}800VA + 800VA + 1{,}200VA \\ \mathbf{VA_{Connected}} &= \mathbf{8{,}540VA} \end{aligned}$$

4.7.2 Demand Load

The actual load used for system sizing after applying the demand factor, representing a more realistic load.

Demand Factor (80%)

It is the ratio of the maximum actual load expected to be used at one time to the total connected load.

The 80% demand factor used is an assumed value for preliminary design purposes. It represents the realistic expectation that not all connected loads operate simultaneously.

Formula:

$$VA_{Demand} = VA_{Connected} \times .80$$

VA_{Demand} = Demand Load
$VA_{Connected}$ = Connected Load
0.80 = Demand Factor

Example:

Determine the demand load of a panel board with 8,540VA connected load supplied at 230V.

Solution:

$$\begin{aligned} VA_{Demand} &= VA_{Connected} \times .80 \\ &= 8{,}540VA \times .80 \\ \mathbf{VA_{Demand}} &= \mathbf{6{,}832VA} \end{aligned}$$

4.7.3 Demand Current

The current corresponding to the demand load of an electrical system.

Formula:

$$I_{Demand} = \frac{VA_{Demand}}{V_{Line}}$$

$$I_{3Demand} = \frac{VA_{Demand}}{\sqrt{3} \times V_{Line}}$$

I_{Demand} = Panel Demand Current (Single-Phase Panel)
$I_{3Demand}$ = Panel Demand Current (Three-Phase Panel)
VA_{Demand} = Demand Load
V_{Line} = Line Voltage

Example:

Determine the demand current, overcurrent protection and conductor & conduit of a panel board with 8,540VA connected load at 230V.

Solution:

$$\begin{aligned} I_{Demand} &= \frac{VA_{Demand}}{V_{Line}} \\ &= \frac{6{,}832VA}{230V} \\ \mathbf{I_{Demand}} &= \mathbf{29.70A} \end{aligned}$$

Demand Current: 29.70A
Overcurrent Protection: Use 1-Pole 40A Circuit Breaker
Conductor & Conduit: Use 2-8.0mm² THWN conductor with 32mm Ø Rigid Steel Conduit

Table 13 Schedule of Loads Typical Format

CKT	DESCRIPTION	QTY	LOAD PER UNIT (W)	TOTAL CIRCUIT LOAD (VA)	VOLTAGE (V)	CURRENT PHASE RATING (A)	OVERCURRENT PROTECTION		CONDUCTOR		CONDUIT	
							POLE	AT	QTY & SIZE	TYPE	Ø	TYPE
1	LIGHTING OUTLET	10	100W	1000VA	230V	4.34A	1	20A	2-3.5MM	THWN STRANDED WIRE	20Ø	Flexible PVC Conduit & PVC Pipe

4.8 FEEDER LOAD

A set of conductors that supplies power from the main distribution point (or upstream panel) to a panel board or subpanel.

4.8.1 Feeder Demand Load

Formula:

$$VA_{Feeder\ Demand} = \Sigma\, VA_{Demand}$$

$VA_{Feeder\ Demand}$ = *Feeder Demand Load*
VA_{Demand} = *Demand Load*

Example:

Determine the feeder demand load of the following panel boards.
– Admin Lighting Panel Demand Load = 6,832VA
– Admin Power Panel Demand Load = 12,000VA
Solution:

$$\begin{aligned} VA_{Feeder\ Demand} &= \Sigma\, VA_{Demand} \\ &= 6{,}832VA + 12{,}000VA \\ \mathbf{VA_{Feeder\ Demand}} &= \mathbf{18{,}832VA} \end{aligned}$$

4.8.2 Feeder Current

Formula:

$$I_{Feeder} = \frac{VA_{Feeder\ Demand}}{V_{Line}}$$

$$I_{3Feeder} = \frac{VA_{Feeder\ Demand}}{\sqrt{3} \times V_{Line}}$$

I_{Feeder} = *Single-Phase Panel Feeder Current*
$I_{3Feeder}$ = *Three-Phase Panel Feeder Current*
$VA_{Feeder\ Demand}$ = *Feeder Demand Load*
V_{Line} = *Line Voltage*

Example:

Determine the feeder current, overcurrent protection and conductor & conduit of a feeder connected load 18,832VA at 230V.

Solution:

$$\begin{aligned} I_{Feeder} &= \frac{VA_{Feeder\ Demand}}{V_{Line}} \\ &= \frac{18{,}832VA}{230V} \\ \mathbf{I_{Feeder}} &= \mathbf{81.88A} \end{aligned}$$

– Feeder Current: 81.88A
– Overcurrent Protection: Use 2-Pole 100A Circuit Breaker
– Conductor & Conduit: Use 2-38.0mm² THWN conductor with 100mm Ø Rigid Steel Conduit

4.9 SERVICE ENTRANCE LOAD

The total electrical demand of the entire building used to size the main service disconnect (main breaker) and service entrance conductors.

Feeder load computation and service entrance load computation follow the same steps; the only difference is the level of the electrical system being considered.

4.9.1 Service Demand Load

The total electrical load of the building after applying applicable demand factors.

Considerations:

- Based on panel demand loads, not connected loads
- Life-safety and critical loads are typically taken at 100% demand
- Used as the basis for computing service current

4.9.2 Service Current

The current drawn by the building service entrance under the calculated service demand load.

Considerations:

- Used to select the main service breaker
- Used to size service entrance conductors
- For three-phase systems, assumes reasonably balanced loads

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