Analysis System Air Conditioning of the Mechanical System in the 2nd Floor MEP Installation of SNL Food Prahyangan

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Abstract— **Centralized ducted air conditioning is an essential element in commercial buildings to maintain temperature and humidity comfort. This study aims to analyze the cooling load, evaluate the adequacy of installed capacity, and formulate operational improvement strategies for the HVAC system on the second floor of the SNL Food Parahyangan building in Batam. Quantitative analysis using the standard rule-of-thumb method of 500 BTU/h $\cdot$ m^2 and the Capacity Adequacy Ratio (R) index indicates that all areas are oversized, with adequacy ratios ranging from 154.51% to 175.65% (total installed/planned capacity of 570.00 PK compared to a basic required load of 348.17 PK). This excessive capacity, particularly in the Main Lobby (175.65%), poses operational risks such as compressor short-cycling, energy waste, and high relative humidity. To resolve these issues, an integrated operational optimization strategy was formulated, comprising: (1) aerodynamic air balancing by adjusting the Lobby Volume Control Damper (VCD) valve to $40\% - 50\%$ openness to redirect excess airflow to Zone A and stabilize humidity at $50\% - 55\%$ RH; (2) implementation of occupancy-based 3-Stage Scheduling combined with weekly compressor Lead-Lag Rotation to save up to 38.5% daily electricity during off-peak hours; and (3) thermostat setpoint adjustment to $24°C - 25°C$ (SNI 6390:2020), deadband expansion to $1.5°C$, and activation of the Daikin inverter Variable Refrigerant Temperature (VRT) mode. The combination of these measures effectively eliminates short-cycling, maintains indoor environmental comfort, and yields daily energy savings of approximately 35% to 40% under normal operating conditions.**

Keywords: Air Conditioning, Ducted AC, Cooling Load, Capacity Adequacy Ratio, Short-Cycling, VCD Air Balancing, Lead-Lag Scheduling, Variable Refrigerant Temperature.

I. Introduction

The structural arrangement and thermal balancing of centralized air conditioning (AC) networks are critical parameters in the modern Mechanical, Electrical, and Plumbing (MEP) building construction workflow [1]. In large-scale commercial retail properties and multi-story facilities, the operational goal of a designed HVAC network extends beyond simply reducing dry-bulb temperature [2]. Modern mechanical ventilation systems must be meticulously calculated to address latent heat gains, facilitate continuous air volume turnover, suppress airborne pollutants and harmful particles, and optimize airflow velocity across complex spatial layouts [3]. Failure to strictly monitor these thermodynamic variables leads directly to rapid heat entrapment inside the building envelope, unnecessary energy waste, and severe indoor microclimate imbalances that compromise human health and comfort standards [4].

In prime commercial retail areas, food handling facilities, and high-density public spaces, real-time climate management is a basic operational requirement [5]. Maintaining uniform indoor temperatures is mandatory to ensure product raw material stability, prevent merchandise degradation caused by uncontrolled humidity fluctuations, and guarantee a clean, hygienic environment in compliance with modern health standards [6]. To provide comprehensive temperature control across expansive building layouts, design engineers favor centralized ducted AC systems over localized ductless split units [7]. This centralized network maximizes air movement distribution through ceiling ductwork, reduces acoustic noise in public zones, and consolidates heavy machinery such as compressors and condensers inside dedicated service rooms for simplified maintenance [8].

Comprehensive technical inspections must be conducted periodically to verify that the installed mechanical AC cooling capacity accurately matches the total heat gain accumulated within the building [9]. A substantial mismatch between factory-rated AC cooling output and localized room heat loads introduces severe operational risks [10]. Undersized AC systems operate continuously without reaching thermostat setpoints, leading to rapid compressor lubricant degradation due to overheating and inflated electricity bills [6], [10]. Conversely, oversized AC equipment forces the system into continuous short-cycling, where the compressor turns off prematurely before the evaporator coil reaches a steady-state cooling condition [4]. This operational failure disrupts moisture extraction capabilities, leaving indoor spaces feeling cold yet humid and uncomfortable [1], [4].

Despite these technical implications, the AC equipment currently operating on the second floor of the SNL Food

Prahyangan building had not previously undergone definitive capacity verification [9]. Existing building records lacked structured baseline calculation profiles, leaving facility managers without an objective benchmark to evaluate AC system efficiency [6], [9]. To resolve this issue, this study performs an in-depth technical evaluation of the centralized ducted AC network in the building [2], [10]. By collecting measured architectural layout drawings, recording manufacturer specifications, and executing sequential load calculations, this paper presents detailed capacity adequacy index figures across all active zones [7], [9]. The resulting empirical data serves as a field-grounded design baseline to optimize building energy consumption, guide future mechanical retrofits, and set a technical standard for commercial MEP engineering in the region [2], [5].

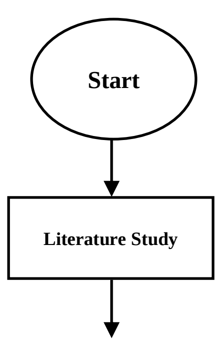
II. METHOD

A. Area Framework and Functional Zone Division

This study employs a quantitative descriptive investigation model to examine heat load characteristics across the second-floor architectural layout of the SNL Food Prahyangan facility in Batam. The operational floor area is structurally categorized into four distinct main zones to evaluate air circulation distribution and cooling demands in each space:

- Zone A (Interactive Playground Zone)
  Represents an active indoor interactive playground environment for various age groups, frequently crowded with roaming visitors engaging in continuous physical activity.
- Zone B (Planned Padel Court Zone)
  Defines a high-ceiling building section planned for a padel sports court requiring high physical exertion.
- Zone C (Expansion Zone)
  Functions as an adjacent commercial expansion area currently under technical planning and mechanical system layout design.
- Zone Lobby
  Acts as the primary visitor reception area, guest handling hub, and thermal boundary zone susceptible to outdoor air infiltration.

The sequential technical workflow developed to execute this capacity audit is illustrated in the methodology flowchart in Fig. 1.



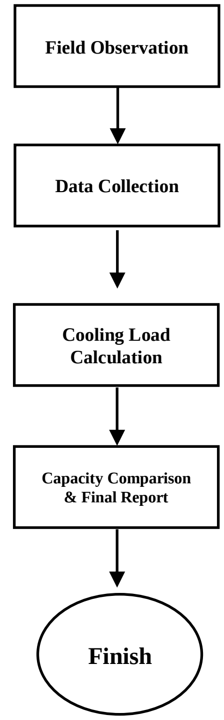


Fig. 1. Flowchart diagram used for HVAC capacity evaluation.

B. Data Collection Procedures and Field Inspection

This technical audit procedure integrates official building documentation analysis with direct on-site physical mapping. Floor measurements, building material layouts, and ceiling heights (H) were extracted from architectural CAD drawings provided by facility management. Direct field inspections were conducted to record the following key parameters:

1. Exact equipment quantities, manufacturer model labels, and factory-rated standard heat removal capacities of active indoor ducted AC units.
2. Airflow pathways along galvanized iron ductwork, structural integrity of air distribution plenum boxes, and potential static pressure leakage points.
3. Physical locations of ceiling supply diffusers and return grilles to analyze indoor air movement dynamics in densely populated areas.

Thermodynamic Modeling and Capacity Calculation Formulas

To technically verify the AC machinery's capability to absorb accumulated indoor heat gain, specific thermodynamic sizing formulas were applied. The basic theoretical required cooling load ($Q_{required}$) needed to counteract solar radiation through glass, wall conduction, and standard electrical equipment heat gain is governed by the following standard commercial formula:

$$Q_{\text{required}} = \text{Area}\ (\text{m}^2) \times 500\ \text{BTU/h} \cdot \text{m}^2 \qquad (1)$$

Where the standard heat factor benchmark of $500\ \text{BTU/h} \cdot$

m^2 serves as the industry baseline for medium-density commercial buildings with ceiling heights up to 5 meters. To align with local marketing terminology used by AC contractors in Indonesia, calculated values were converted to *Paardekracht* (PK) units using the conversion equation:

$$\text{Required PK} = \frac{Q_{\text{required}}}{9{,}000\ \text{BTU/h}} \tag{2}$$

The final adequacy index (R) evaluating whether installed AC networks are sufficient or oversized relative to design thresholds is calculated mathematically using the Capacity Adequacy Ratio:

$$R = \frac{Q_{\text{installed}}}{Q_{\text{required}}} \times 100\% \tag{3}$$

Where $Q_{installed}$ represents the total factory-rated cooling output (BTU/h) aggregated from equipment nameplate data. A result of $R \geq 100\%$ indicates that the installed equipment capacity is technically adequate to handle the thermal load of the building.

III. RESULTS AND DISCUSSION

A. Mechanical System Layout and Specification Mapping

Based on official technical drawings and physical field inspections, the spatial deployment of the centralized ducted AC system on the second floor of SNL Food Prahyangan was fully mapped. The facility layout includes 30 active and planned ducted split units, each possessing a factory-rated capacity of 171,000 BTU/h (equivalent to 19.00 PK per compressor unit).

The primary supply ductwork network, branch lines, and ceiling diffusers across all building areas are detailed in the ductwork layout plan (Fig. 2). Complementing the air distribution system, condensate drain piping routing water away from indoor fan coil units is mapped in Fig. 3.

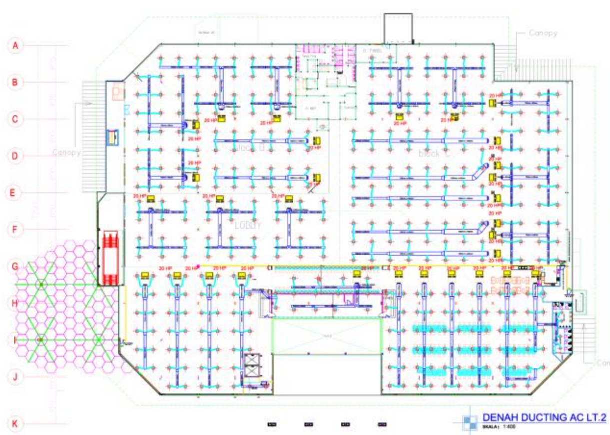


Fig. 2. Centralized ducted AC mechanical layout plan on the second floor

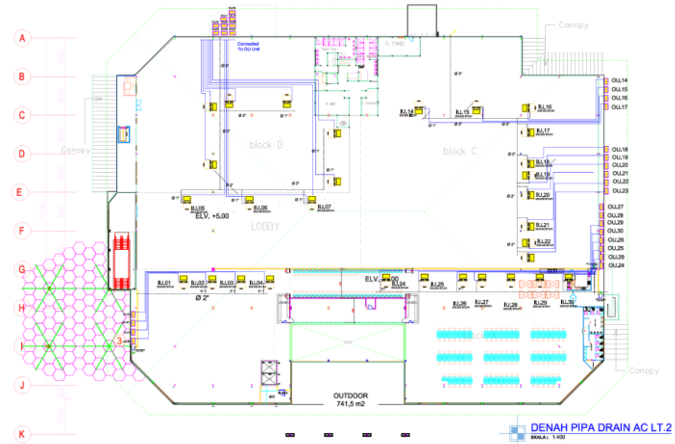


Fig. 3. Condensate drain piping network serving mechanical cooling units on the second floor

On-site physical inspections confirmed that the outdoor condensing plant utilizes modular high-capacity AC units installed along a dedicated service balcony corridor (Fig. 4). Machine nameplates (Fig. 5) verified the deployment of Daikin RZUR500PY14 commercial outdoor units operating on eco-friendly R-410A refrigerant, with a measured electrical power input of 26.74 kW and an operational weight of 291 kg per unit.

Fig. 4. A row of modular commercial outdoor air conditioning units installed along the building's service balconies.

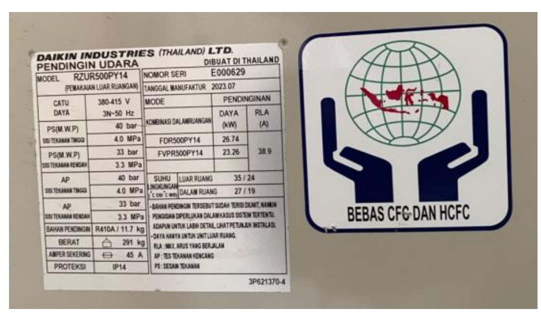


Fig. 5. The manufacturer's technical specification label of the Daikin outdoor unit RZUR500PY14 noted during the field inspection.

Indoors, cold air distribution relies on high-static ducted indoor Fan Coil Units (FCUs) suspended from the ceiling structure connected directly to insulated plenum boxes (Fig. 6). Conditioned air flows through rectangular galvanized steel main ducts (Fig. 7) suspended below steel roof trusses. Branch supply ductwork transitions into flexible insulated ducts connected to square supply diffusers mounted on exposed ceiling frames (Fig. 8).

Fig. 6. Indoor Fan Coil (FCU) unit with insulated air divider (plenum) box.

Fig. 7. The main cold air duct is insulated rectangular galvanized zinc that runs under the steel roof frame.

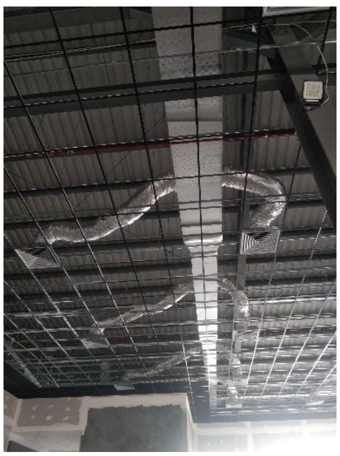


Fig. 8. Flexible branch ducts that supply air to the square ceiling vents inside the open ceiling structure.

B. Capacity Adequacy Evaluation and System Conformity

To evaluate the technical suitability of the installed equipment, calculated heat load distributions were cross-referenced against factory cooling outputs for active and planned units:

1. **Zone A (Interactive Playground Zone):**
   Known:
   - Floor Area (A) = 2,178.0 m^2
   - Commercial Thermal Load Coefficient =500 $\text{BTU/h} \cdot \text{m}^2$
   - Conversion Divisor = 9,000 BTU/h per PK

   Formula:
   - $Q_{\text{required}} = \text{Area} \times 500\ \text{BTU/h} \cdot \text{m}^2$
   - Required PK $= \frac{Q_{\text{required}}}{9{,}000\ \text{BTU/h}}$

   Calculation:
   - $Q_{\text{required}} = 2{,}178.0 \times 500 = 1{,}089{,}000\ \text{BTU/h}$
   - Required PK $= \frac{1{,}089{,}000}{9{,}000} = 121.00$ PK

   Based on the calculation results for Zone A, it is found that the interactive playground zone requires a minimum baseline cooling capacity of 1,089,000 BTU/h which is technically equivalent to 121.00 PK of refrigeration output power to sustain ideal indoor thermal comfort.

2. **Zone B (Planned Padel Court Zone)**
   Known:
   - Floor Area (A) = 1,328.0 m^2
   - Commercial Thermal Load Coefficient =500 $\text{BTU/h} \cdot \text{m}^2$
   - Conversion Divisor = 9,000 BTU/h per PK

   Formula:
   - $Q_{\text{required}} = \text{Area} \times 500\ \text{BTU/h} \cdot \text{m}^2$
   - Required PK $= \frac{Q_{\text{required}}}{9{,}000\ \text{BTU/h}}$

   Calculation:
   - $Q_{\text{required}} = 1{,}328.0 \times 500 = 664{,}000\ \text{BTU/h}$
   - Required PK $= \frac{664{,}000}{9{,}000} = 73.78$ PK

   Based on the calculation results for Zone B, it is found that the planned padel court zone requires a minimum baseline cooling capacity of 664,000 BTU/h which is technically equivalent to 73.78 PK of refrigeration output power to sustain ideal indoor thermal comfort.

3. **Zone C (Expansion Zone)**
   Known:
   - Floor Area (A) = 2,177.0 m^2
   - Commercial Thermal Load Coefficient

=500 BTU/h · m²

- Conversion Divisor = 9,000 BTU/h per PK

Formula:

- $Q_{\text{required}} = \text{Area} \times 500\ \text{BTU/h} \cdot \text{m}^2$
- Required PK $= \frac{Q_{\text{required}}}{9{,}000\ \text{BTU/h}}$

Calculation:

- $Q_{\text{required}} = 2{,}177.0 \times 500 = 1{,}088{,}500\ \text{BTU/h}$
- Required PK $= \frac{1{,}088{,}500}{9{,}000} = 120.94$ PK

Based on the calculation results for Zone C, it is found that the expansion zone requires a minimum baseline cooling capacity of 1,088,500 BTU/h, which is technically equivalent to 120.94 PK of refrigeration output power to sustain ideal indoor thermal comfort.

4. **Lobby Zone:**

Known:

- Floor Area (A) = 584.1 m²
- Commercial Thermal Load Coefficient =500 BTU/h · m²
- Conversion Divisor = 9,000 BTU/h per PK

Formula:

- $Q_{\text{required}} = \text{Area} \times 500\ \text{BTU/h} \cdot \text{m}^2$
- Required PK $= \frac{Q_{\text{required}}}{9{,}000\ \text{BTU/h}}$

Calculation:

- $Q_{\text{required}} = 584.1 \times 500 = 292{,}050\ \text{BTU/h}$
- Required PK $= \frac{292{,}050}{9{,}000} = 32.45$ PK

Based on the calculation results for the Lobby zone, it is found that the entry lobby requires a minimum baseline cooling capacity of 292,050 BTU/h which is technically equivalent to 32.45 PK of refrigeration output power to sustain ideal indoor thermal comfort.

5. **Installed / Planned Capacity Conversion:**

Known:

- Single Asset Factory Rating = 171,000 BTU/h
- Zone A Asset Count = 11 Units
- Zone B Asset Count = 6 Units
- Zone C Asset Count = 10 Units
- Lobby Asset Count = 3 Units
- Conversion Divisor = 9,000 BTU/h

Formula:

- $Q_{\text{installed}} = \text{Asset Count} \times 171{,}000\ \text{BTU/h}$
- Installed PK $= \frac{Q_{\text{installed}}}{9{,}000\ \text{BTU/h}}$

Calculation:

- Zone A: $11 \times 171{,}000 = 1{,}881{,}000$ BTU/h → $\frac{1{,}881{,}000}{9{,}000} = 209.00$ PK
- Zone B: $6 \times 171{,}000 = 1{,}026{,}000$ BTU/h → $\frac{1{,}026{,}000}{9{,}000} = 114.00$ PK
- Zone C: $10 \times 171{,}000 = 1{,}710{,}000$ BTU/h → $\frac{1{,}710{,}000}{9{,}000} = 190.00$ PK
- Lobby: $3 \times 171{,}000 = 513{,}000$ BTU/h → $\frac{513{,}000}{9{,}000} =$ 57.00 PK

Consequently, the actual matching calculations convert the factory asset counts into cumulative cooling capacities, yielding an installed total of 209.00 PK for Zone A, a planned total of 114.00 PK for Zone B, a planned total of 190.00 PK for Zone C, and an installed total of 57.00 PK for the Lobby zone.

The analytical matching matrix computing the Capacity Adequacy Ratio (R) for each independent zone is organized inside the data layout presented in Table I.

TABLE 1.

COMPREHENSIVE CAPACITY COMPARISON MATRIX FOR THE SECOND FLOOR CENTRALIZED HVAC NETWORK

Name Room	Area (m²)	Required (BTU/h)	Required (PK)	Installed / Planned (BTU/h)	Installed (PK)	Adequacy Status (R)
Zone A	2,178.0	1,089,000	121.00 PK	1,881,000	209.00	Adequate
Zone B	1,328.0	664,000	73.78 PK	1,026,000	114.00	Design OK

Zone C	2,177.0	1,088,500	120.94 PK	1,710,000	190.00	Design OK
Lobby	584.1	292,050	32.45 PK	513,000	57.00	Adequate

The quantitative evaluation derived from Table I demonstrates that the mechanical cooling infrastructure exhibits significant capacity surpluses across all four zones. To visualize the distribution margins between structural cooling demands and active equipment tonnages, the comparative relationships are tracked in the analytical chart shown in Fig. 9.

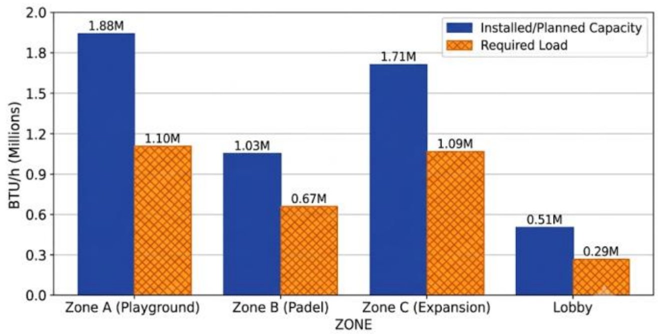


Fig. 9. Comparative distribution chart displaying required cooling load vs. installed mechanical equipment capacity

C. Discussion and Operational Implications

Empirical data collected in Table I and visualized in Fig. 9 reveals critical operational insights regarding the second-floor AC network. Technical data indicates that the centralized ducted split AC infrastructure possesses an extensive cooling safety margin, with Capacity Adequacy Ratios (R) consistently exceeding 150% across all observed building areas.

In Zone A (interactive playground), the AC equipment provides a total cooling output of $1{,}881{,}000$ BTU/h (209.00 PK) against a calculated baseline load requirement of $1{,}089{,}000$ BTU/h (121.00 PK), yielding a surplus capacity ratio of 172.72%. In daily commercial operations, a large safety factor in indoor entertainment spaces is effective for absorbing fluctuating heat spikes. Dense crowds during peak operating hours generate sensible body heat and latent heat from respiration. This large equipment reserve allows ducted fan coil units to rapidly pull down space temperatures, maintaining thermal stability and preventing localized heat stagnation.

However, the extremely high adequacy ratio in the Main Lobby, reaching 175.65% ($513{,}000$ BTU/h installed vs. $292{,}050$ BTU/h required), presents mechanical and energy efficiency challenges. Although excess capacity helps counteract outdoor air infiltration from open entrance doors, operating severely oversized AC machinery during low-occupancy periods introduces technical risks. The primary issue is compressor short-cycling, where the AC system reaches thermostat setpoints prematurely. Consequently, the compressor shuts off before the evaporator coil reaches a steady-state cooling temperature. Because moisture extraction requires continuous air contact over a cold evaporator coil, premature compressor shutdown halts dehumidification. This operational condition leaves excess humidity in the air stream, making the room feel cold yet humid and clammy, while accelerating electrical contractor switch wear.

For future expansion projects in Zone B and Zone C, planned capacity allocations remain well within safe engineering margins (154.51% and 157.10%, respectively). This forward-looking design ensures that when the padel court and commercial spaces become fully operational, the designated AC array will handle exterior wall heat transfer and solar radiation without overloading compressor motors.

To optimize building energy efficiency, eliminate compressor short-cycling, and extend machinery lifespan, facility managers must implement mutually supportive corrective actions. This approach integrates aerodynamic air balancing using Volume Control Damper (VCD) valves on primary ductwork—reducing excess airflow in low-occupancy spaces like the Lobby and redirecting it to high-demand zones—with occupancy-based 3-Stage Scheduling, a compressor Lead-Lag Rotation system, and intelligent thermostat and inverter tuning. Details of these corrective measures are presented in Table II.

TABLE II.
HVAC SYSTEM INTEGRATED OPERATIONAL OPTIMIZATION STRATEGY MATRIX

Corrective Action	Existing Condition	Recommended New Settings	Building Operational Benefits
Airflow Balancing (VCD Air Balancing).	Lobby VCD valve fully open (100%).	Reduce Lobby VCD valve opening to $40\% - 50\%$ to redirect excess cold air ($400 - 600$ CFM) to Zone A.	Stabilizes Lobby AC runtime ($22 - 28$ minutes per cycle), lowers humidity to ideal levels ($50\% - 55\%$ RH), and eliminates cold clammy air.

AC Operation Schedule (3-Stage Scheduling)	All 14 AC units (266.00 PK) run continuously all day.	Morning (10:00–13:00 WIB): Run 6 units (114.00 PK) during low load. Afternoon (13:00–17:00 WIB): Run 10 units (190.00 PK) during medium load. Evening/Weekend (17:00–22:00 WIB): Run 14 units (266.00 PK) during peak load.	Reduces daily electricity consumption by up to 38.5% during low-occupancy periods.
Compressor Rotation (Lead-Lag Rotation)	Specific AC units operate continuously while others remain idle.	Rotate Lead (primary) and Lag (secondary) unit designations weekly via BAS/manual SOP.	Equalizes running hours across all compressors, preventing premature component failure.
Thermostat Setpoint (T_{set})	Set excessively cold at 20°C − 21°C.	Increase setpoint to 24°C − 25°C in compliance with energy conservation standards (SNI 6390:2020).	Reduces compressor workload by approximately 12% − 15% while maintaining optimal thermal comfort.
Temperature Histeresis (Deadband)	Very narrow tolerance (0.5°C), causing rapid AC cycling.	Expand deadband tolerance to 1.5°C (AC re-activates at 25.5°C and turns off at 24.0°C).	Prevents frequent compressor short-cycling.
Inverter Setting (Daikin VRT Mode)	Non active	Enable VRT Mode to automatically modulate evaporating temperature (raising T_e to 9°C − 11°C during low load).	Inverter smoothly ramps down power during low-demand periods without turning off the compressor

The implementation of the measures outlined in Table II demonstrates that operational challenges resulting from capacity oversizing can be effectively mitigated through integrated control system optimization and operational management. By balancing airflow, structuring operation schedules, and configuring thermostats accurately, AC compressors operate more smoothly and stably (22 − 28 minutes per active cycle). Consequently, indoor air humidity is maintained within comfortable limits, electrical inrush current spikes are minimized, and daily electricity consumption is reduced by approximately 35% to 40% on typical weekdays.

IV. CONCLUSION AND RECOMMENDATIONS

Based on cooling load analysis, capacity evaluations, and operational strategy modeling of the second-floor AC system at SNL Food Parahyangan Batam, it is concluded that the installed and planned AC infrastructure (570.00 PK) provides highly adequate capacity to absorb the building's baseline thermal load (348.17 PK), yielding Capacity Adequacy Ratio (R) values ranging from 154.51% to 175.65%. However, this substantial excess capacity, particularly in the Main Lobby (175.65%), induces operational short-cycling during low-load conditions. This results in cold yet clammy indoor air due to premature dehumidification interruption, while increasing wear on starter contactors and causing frequent startup inrush current spikes.

These operational challenges can be resolved through an integrated operational management strategy. Aerodynamic air balancing by adjusting the Lobby Volume Control Damper (VCD) valve to 40% − 50% openness successfully redirects 400 − 600 CFM of excess airflow to Zone A, stabilizes the Lobby compressor runtime between 22 and 28 minutes, and reduces relative humidity to an ideal range of 50% − 55% RH. Combining an occupancy-based 3-Stage Scheduling scheme with weekly compressor Lead-Lag Rotation equalizes running hours across all compressors and reduces power consumption by up to 38.5% during off-peak periods. Furthermore, adjusting thermostat setpoints to 24°C − 25°C (SNI 6390:2020), expanding the hysteresis deadband to 1.5°C, and activating Daikin VRT mode maximizes inverter modulation efficiency without repetitive compressor cycling, yielding potential daily energy savings of 35% to 40% under normal operating conditions.

To ensure sustainable HVAC performance and energy efficiency, facility engineers and management are advised to immediately execute airflow commissioning using anemometers at all Lobby and Zone A diffusers following VCD adjustments. Management should also establish a weekly digital logbook to track daily compressor running hours, ensuring consistent execution of the Lead-Lag rotation SOP. Additionally, preventive maintenance including quarterly cleaning of indoor FCU air filters and outdoor condenser coils must be conducted routinely to prevent static pressure losses and maintain optimal system heat transfer efficiency.

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