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# COOLING ENERGY ASSESSMENT OF AN EXISTING DATA CENTER IN HANOI

# ĐÁNH GIÁ NĂNG LƯỢNG CỦA HỆ THỐNG LÀM MÁT TRONG TRUNG TÂM DỮ LIỆU HIỆN HỮU TẠI HÀ NỘI

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**Abstract:**

Demand for information handling and processing applications has grown significantly in response to the exponential expansion of data trafficking, data processing, e-learning, social networking, digitization of services, and general shift to digital platforms. The enormous amounts of data produced and used daily are stored and handled on a data center, including servers, routers, firewalls, and storage devices. The deployment of data centers as essential assets for any organizations is growing and calls for attention on their lifetime and efficiency. After many years operating, it is particularly important to assess the critical facilities. The assessment is crucial for the operational capacity of the data center to be kept and optimized as well as for the assessment of its future development capacity to meet the growing needs. This paper describes a thorough approach for evaluating typical data center projects to find hazards and risks that might compromise the availability or safety of data centers. It also offers ideas for enhancing the dependability, resilience, and efficiency of present data center architecture with low operational disturbance. We aims to evaluate the energy efficiency and risk of present data centers so developing a plan for improving and preserving their performance in a society going more digital. The approach consists of a thorough analysis of the current DC's infrastructure, the identification of possible weaknesses, and the formulation of plans to reduce the found hazards. The case study assessment helps data center operators to better run their facilities, so ensuring their resilience and robustness in the presence of changing needs and possible hazards. This pro-active data center assessment approach is essential to enable the continuous digital transformation deployment and protect the vital services modern of DC's owners.

**Keywords:**

Data center, Precision cooling, PUE, Facility assessment, Resiliency, Robustness

**Tóm tắt:**

Nhu cầu sở hữu và phát triển các ứng dụng của công nghệ thông tin tăng đáng kể nhằm đáp ứng sự tăng trưởng theo cấp số nhân của việc lưu thông – xử lý dữ liệu, học trực tuyến, mạng xã hội, dịch vụ số hóa và chuyển đổi sang nền tảng số. Lượng dữ liệu khổng lồ này được lưu trữ và xử lý tại trung tâm dữ liệu (DC), bao gồm máy chủ, bộ định tuyến, tường lửa và thiết bị lưu trữ. Triển khai các DC xem như tài sản thiết yếu cho các công ty và tổ chức đang ngày càng tăng và đòi hỏi sự chú ý đến tuổi thọ và hiệu quả vận hành. Sau nhiều năm vận hành, đặc biệt quan trọng cần chú ý kiểm toán hạ tầng trọng yếu. Phân tích và đánh giá rất quan trọng để duy trì, tối ưu hóa vận hành DC, đánh giá khả năng phát triển trong tương lai nhằm đáp ứng nhu cầu tăng trưởng. Nghiên cứu này mô tả một cách tiếp cận toàn diện để đánh giá điển hình dự án DC nhằm tìm ra các sự cố và rủi ro có thể gây tổn hại đến tính sẵn sàng, an toàn vận hành. Bài báo cũng đưa ra các ý tưởng nhằm nâng cao độ tin cậy, khả năng phục hồi và hiệu quả của hạ tầng DC hiện hữu với mức độ gián đoạn hoạt động thấp. Với mục tiêu đánh giá hiệu quả sử dụng năng lượng và rủi ro trong các DC, nhằm xây dựng kế hoạch cải thiện và duy trì hiệu suất của các hạ tầng này trong bối cảnh ngày càng phát triển số hóa. Phương pháp tiếp cập tập trung phân tích chi tiết hạ tầng thiết bị hiện hữu, đánh giá và xác định các rủi ro tiềm ẩn và lên kế hoạch giảm thiểu các mối nguy hiểm được phát hiện. Việc phân tích đánh giá trường hợp cụ thể giúp những kỹ sư vận hành hạ tầng của họ tốt hơn, đảm bảo khả năng phục hồi và độ bền bỉ trước những nhu cầu thay đổi và các mối nguy hiểm tiềm ẩn. Phương pháp đánh giá chủ động này rất cần thiết để cho phép phát triển chuyển đổi kỹ thuật số và bảo vệ việc cung cấp những dịch vụ quan trọng của các công ty.

**Keywords:**

Trung tâm dữ liệu, Điều hòa chính xác, PUE, Kiểm toán hạ tầng, Bền bỉ, Khả năng phục hồi.

## 1. INTRODUCTION

The growth in data trafficking, data processing, e-learning, social networking, internet of things technology, artificial intelligence, digitization of services and in general, the simple fact that almost everything is shifting digital, necessitates an ever-increasing demand in information handling and processing. Data center (DC) is a fundamental infrastructure of computers and networking equipment (or IT equipment) to collect, store, process, and distribute huge amounts of data for a variety of applications such as Cyber–Physical–Social Systems, business enterprises and social networking. DCs consume an important amount of electricity, nearly 3% - 5% per year of global electricity consumption [1-3]. Besides, maintaining stable and continuous operation of DC is a mandatory requirement; in particular, cooling and power infrastructure is called critical infrastructure for DC uptime availability level. Many technical recommendations and standards for designing DC infrastructure are described in the Uptime Institute or TIA-942 [2-4]. In order to ensure stable, safe and continuous 24/7 operation of the data center, the data center physical infrastructure generally consists of four main facilities: the IT facilities, Power facilities, Cooling facilities and other facilities. DCs facilities are often designed according to recommended standards or do not comply with standards. After a period of operating IT equipment, evaluating operational performance; security (affecting uptime service availability) is especially necessary. According to the 2023 and 2024 Uptime Institute global survey of IT and data center managers, power continues to be the leading cause of data center incidents and outages. Following these survey reports, cooling was responsible for 19% of the second impactful incidents or outages at data centers [4].

It is critical to conduct a thorough analysis and effectively manage energy usage, especially cooling issues within data centers, as they support the complex needs of businesses and governments, as well as the growing demand for digital services. By proactively addressing these challenges, DC operations can be maintained in a reliable and efficient manner, ensuring the continued provision of essential digital services. This emphasizes the urgent necessity of a strategic energy management approach within data centers to ensure their continuous operation in the face of ever-increasing demand and the changing digital services landscape. This thesis will discuss the principles and process of assessing a data center to categorize it, identify key performance indicators, and reduce potential downtime due to outages caused by the aforementioned reasons. We will also investigate the energy efficiency mainly concerning cooling aspects of data centers, including their principles, measurements, and the necessary numbers of the corresponding statistics in order for a data center to operate year-round with minimal downtime and risk. Benefits of a data center cooling assessment [5- 8]:

- A comprehensive report provides power and cooling utilization analysis and identifies key infrastructure constraints that inhibit full space utilization.
- The measurement of existing conditions indicates areas where temperature and humidity levels are not within tolerances established by industry standards and equipment manufacturers.
- Measurement of the data center electrical infrastructure loads provides an accurate assessment of the actual data center power and heat loads and identifies excessive load conditions that can compromise existing reliability.
- Measurement of present temperature conditions provides visual representation of excessive rack inlet temperatures and other potential hot spots within the data center.

This paper will perform a comprehensive audit of an example DC with one of the highlights is exploring its critical infrastructure, like the power and cooling systems. We will provide a case study of a small data center in Hanoi to gain deeper understanding in the baseline current distributions such as power and airflow. Then we will conduct a performance analysis of the data we gathered, comparing it to the results from the simulation to find out if the data matches or goes as expected. To perform a thorough audit of said existing DC, we will be exploring the deficiencies in the power and cooling system, as well as physical infrastructure space. On-site measurements and data collection are required for statistics such as energy supply and energy improvements. Lastly, to provide a clear roadmap in detecting defects and suggesting improvements, we calculate the essential recognized KPI, identify risks that can affect the data center’s safety and availability, and provide recommendations based on the risk found as well as following the standard practices in the industry, all according to the established guidelines.

## 2. APPROACH AND TECHNIQUE

### 2.1. Technical assessment approach

The thorough data center audit aimes to find weaknesses in the areas of power, cooling, and physical infrastructure and offer a clear road of development. Following on-site measurements and data collecting by student and teacher teams, the audit schedule will include first data analysis and document review then will see site visits for data revaluation, and report writing finished at the end of the month. The audit result concentrated on computing recognized key performance indicators (KPIs) for power, cooling, and physical space, identifying risks and threats that could affect the safety and availability of the data center, and, if at all possible, providing recommendations if only to enhance robustness, resiliency, and efficiency of the current data center infrastructure with minimum interruptions to operations, so improving the goal of general reliability and operational efficiency. In the context, we present the method outlined in **Figure 1.**

IT equipment and precision air conditioning systems are the primary energy consumers, as previously mentioned in Section 1. It is crucial to assess the cooling configuration and equipment layout in the data hall to ensure the cooling of IT devices to ensure energy efficiency and safety [2-7]. Precision air conditioners consume a substantial amount of electrical energy (35 to 50%) as a result of their continuous provision of precision cold air energy to cool IT equipment, regulate the relative humidity in DC, and ensure that the operating environment for IT equipment is stable and resilient. Consequently, the calculation and design of power supply capacity, including electricity and heat for DCs are contingent upon the adherence to thermal guidelines and design specifications. Additionally, information technology equipment necessitates electrical energy and generates heat in proportion to the energy consumed by electricity. As accurately evaluate a data center as possible, there are many steps to be included such as data collection at the site such as temperature of the cold supply to the IT rack-row, the humidity of each rack, Computational Fluid Dynamics (CFD) simulation tool will also be incorporated to serve as a guideline to evaluate the collected dataset [3, 9]. In this research, we will evaluate if it's in compliance of the Tier III indicated by Uptime Institute [3-5], identify points of failure if it exists any, and formulate methods to optimize energy efficiency. We use the ASHREA thermal guidelines as reference for IT environment operation recommendations [10].

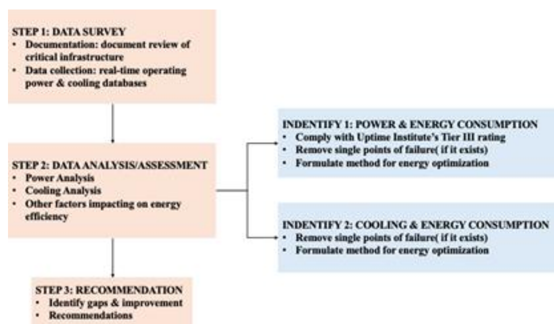


**Figure 1. Flow chart of assessment procedure**

## 2.2. Site Overview: Baseline current situation

This evaluation is being carried out on the data center of an enterprise that is currently operating in the banking sector since 2018. This data center is a "retrofit" type in 2023 and is situated in Vietnam. The IT racks have a capacity of 250 kW and consist of 36 IT racks. The DC layout is shown in the schematic below. The **Tables** will provide additional information to help you understand the design more fully.

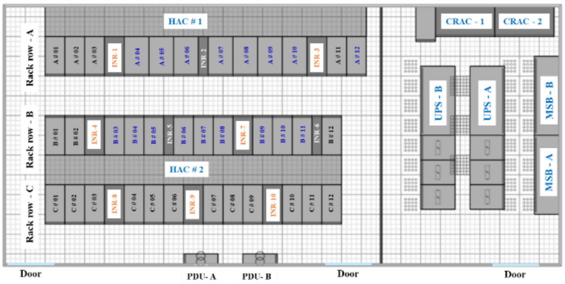


**Figure 2. IT Hall and Power Room on 2D layout**

**Table 1. Data center components and Characteristics**

| Legend | Description |
|---|---|
| Rack row | Rack row – A with 12 IT rack (A # 01 to A # 12)<br>Rack row – B with 12 IT rack (B # 01 to B # 12)<br>Rack row – C with 12 IT rack (C # 01 to C # 12) |
| INR | Inrow cooling consisted of 02 types:<br>• INR-1; INR-3; INR-4; INR-7; INR-8; INR-9; INR-10 (Dimension : 2000mmH x 600mmL x 1200mmD)<br>• INR-2; INR-5; INR-6 (Dimension : 2000mmH x 300mmL x 1200mmD) |
| HAC | Hot Ailse air Containment: HAC # 1 and HAC # 2; consists of a physical barrier that guides hot exhaust airflow back to the Inrow air-return. |
| PDU-A; PDU-B | A power distribution unit (PDU) is a device fitted with multiple outputs designed to distribute electric power, especially to racks of computers and networking equipment located within a data center. |
| CRAC-1; CRAC-2 | Inroom precision air-conditioner cooling: Act as a cooling air supply for the electronic equipment in the Electrical, Battery, UPS |
| UPS-A; UPS-B | Uninterruptible Power Supply (UPS) systems are installed in data centers to provide constant power to IT equipment. During grid outages, the UPS systems with battery backup must provide enough power for at least 10 minutes to back up the data and start the backup generators. |
| MSB-A; MSB-B | The switchboard includes the main switch and circuit breakers. Act as a central controller board for the data center, providing electricity to the entire data center. |

**Table 2. Critical Power and Cooling characteristics**

| | |
|---|---|
| Transformer | 01 x 750 kVA (22 kV/ 0.4 kV; Three-phase; 50 Hz) |
| Engine Generator | 02 x 660 kVA |
| UPS for IT loads | 200 kVA/ 200 kW |
| UPS for Cooling loads | None |
| Floor PDUs | 02 x units; each having 277 kVA/ 277 kW (maximum rating) |
| Chiller | None |
| CRAH units | 10 x INROWs (close-coupled cooling, air-cooled) in IT room (data hall)<br>02 x CRACs (downflow cooling, air-cooled) in technical room |
| Current Tier rating | III, Uptime Institute (for Power and Cooling infrastructures) |

## 3. RESULTS AND DISCUSSION

### 3.1. Cooling Thermal Profiles

Using the monitoring tools that are used to monitor and control the data center, we gathered the relevant data for each Row A, B and C shown below (**Table 3-5** and **Figure 3 and 4**).

Comparing the gathered data to the ASHREA Psychrometric chart of recommended zone for IT racks, we can see that all the row A, B, C (**Figure 5**) have adequate intlet cooling air temperature for every rack but one rack C12. In the humidity section, there are some exception racks where their humidity reaches above 60%, which does not comply with the ASHREA standard (rack A01-03, B01-05, C01-03-05). It is advisable to equip the DC with extra deodorizing tools to help to enable the restoration affecting racks' humidity back to the recommended range.

**Figure 3. Humidity and Cold air Temperature values in each IT Rack**

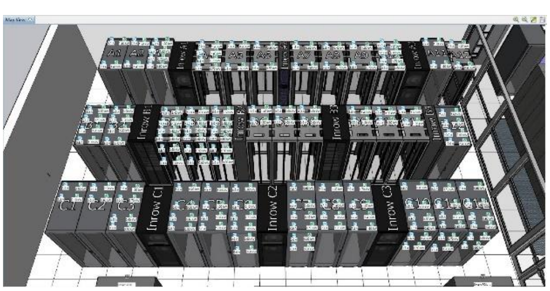

**Figure 4. Power consumption or Thermal heat load at the rack location monitoring of the data center**

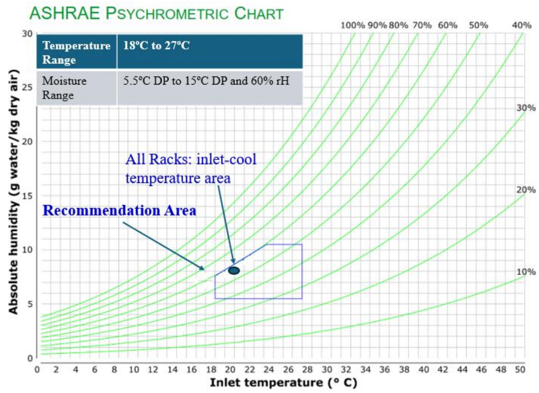


**Figure 5. ASHRE Psychrometric chart**

### 3.2. Thermal Profiles Simulations

We use a commercial CFD tool thanks to Schneider Electric [3, 9] which has been widely used to improve data center thermal management, avoiding oversizing design, replicating and evaluating the heat distribution inside an IT room using technical specifications of the inrows coolings and data gathered from observing activities in the DC (**Figure 6**). This also helps assess the future possibility of optimal functioning, that of inrow equipment redundancy. Using a CFD simulation tool, one can evaluate the temperature, airflow and thermal distribution in several design possibilities including several configurations of the cold aisle, hot aisle, and IT racks. Accurate forecasts of the airflow rates through data hall and the temperatures at the rack's inlet of the CFD study can be obtained from their output. This has proved to be helpful in the design of data centers since it lets the designer confirm the cooling system design prior to deployment.

- Knowing how the location of IT racks in a real-world installation will impact the capacity of the cooling system to satisfy the cooling demand of the data hall helps data center managers.
- By turning off or on standby components in the CFD model, run simulations of several failure situations. Analyze whether the last cooling system can maintain the IT demand.

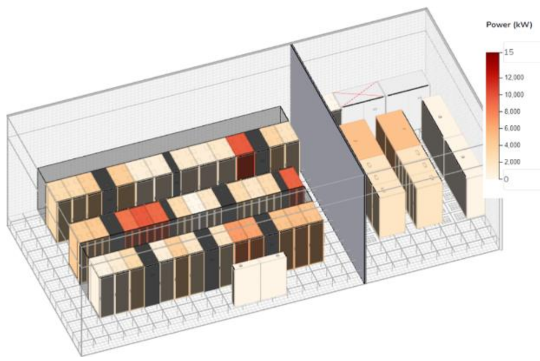


**Figure 6. Data center layout with power distribution in real-time operation**

We can assess the potential for inrows to function optimally, which refers to the current cooling system design that allows for regional redundancy. This demonstrates that the IT room's cooling system meets all the recommended Uptime Tier III standards. The simulation results are shown in the following illustration (**Figure 7 to 10**). Although the temperature of the returned hot air is higher, it remains within the best practices, 30ºC to 38ºC.

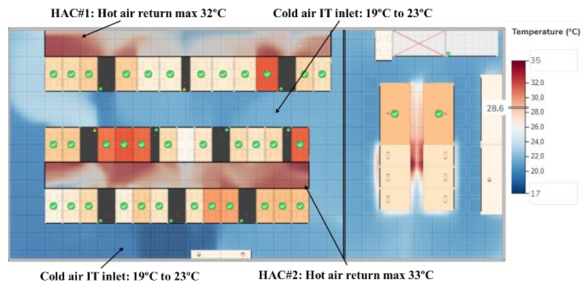


**Figure 7. Top view - Cold and Hot air distribution in the IT room (simulated results with actual parameters of Inrow: return air temperature and airflow supply)**

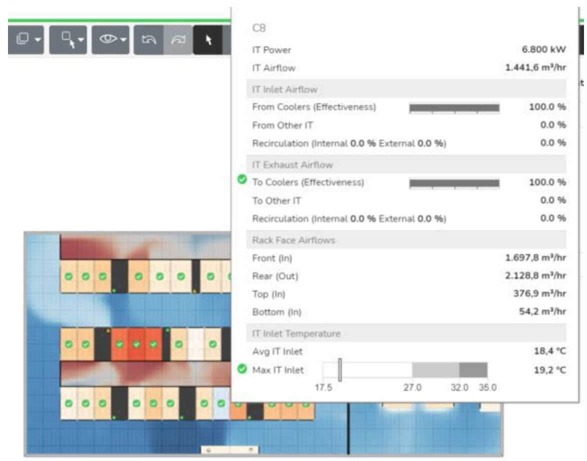


**Figure 8. Top view - air distribution in the C08 (simulated results with actual parameters: return air temperature and airflow supply)**

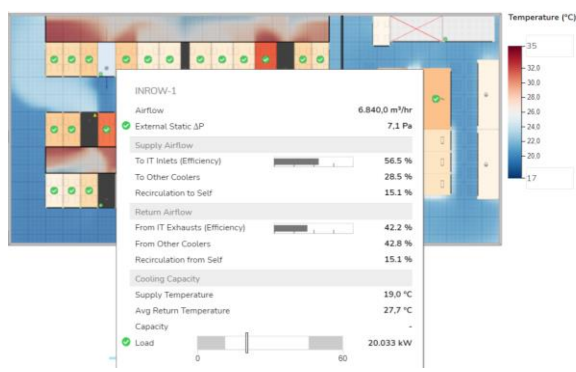


**Figure 9. Inrow cooling capacity (simulated results with actual parameters: return air temperature and airflow supply)**

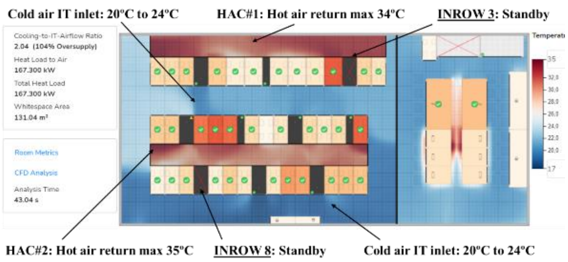


**Figure 10. Optimal operating for Cooling efficiency with 02 Inrows in standby mode (called local backup)**

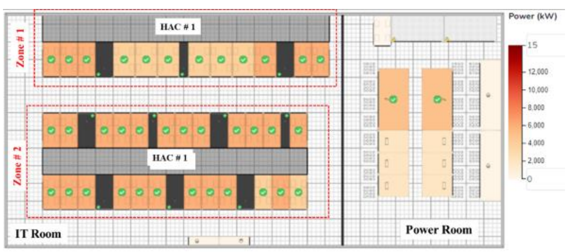


**Figure 11. Operating recommendation following the ASHRAE guidelines**

From the design schematic of the data center, the intended is:

- Average IT rack load at 5.56 kW (estimated), multipled by 36 Racks, then the total is about 200 kW
- Data hall wasted heat load is reserved at 10 kW
- Total required cooling for data hall is determined at 210 kW
- Total sensible cooling capacity will be provided by cooling system at least 210 kW with N+1 (based on largest unit redundant)

Considering the initial concept for the IT room as well as the cooling layout, we came to these suggestions divided into zones as dictated in **Figure 11:**

- **Zone #1:**

02 INROWs (smart cooling: 30 kW/set; airflow: 6900 $m^3$/h each) and 01 INROW (smart cooling: 22 kW/set; air flow: 5700 m3/h per unit); total 82 kW reasonable cooling capacity; total air flow: 19,500 $m^3$/h. The Cooling System guarantees a total airflow of at least 212 $m^3$/ hour/ kW for each rack, as per ASHRAE guidelines [2]. The necessary airflow from the IT load of 12,720 $m^3$/ h is guaranteed.

Nevertheless, as HAC#1 is severely restricted, we recommend that the current IT load be reduced to 70% of the IT rating to guarantee 24/7 sustained operations and comply with Tier III classifications. Then, the operating mode for cooling in the N+1 spare room is satisfied.

- **Zone #2:**

05 INROWs (smart cooling: 30 kW/set; air flow: 6900 $m^3$/h each) and 02 INROWs (smart cooling: 22 kW/set; air flow: 5700 $m^3$/h per unit); total reasonable cooling capacity is 194 kW; total airflow provided: 45,900 m3/h; It is evident that the Cooling System's total airflow is equivalent to the guaranteed airflow required by the IT load (29,680 $m^3$/h).

Nevertheless, HAC#2 is severely restricted. To guarantee continuous operations and adhere to Tier III classifications, we recommend that the current IT load be reduced to 70% of the IT rating. Operating mode for cooling in the N+1 spare room is satisfied.

**Table 3. Data gathered from Row A to Row C with underline humidities values**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Row A*** | | | | | | | | | | | | |
| *Rack* | Rack 1 | Rack 2 | Rack 3 | Rack 4 | Rack 5 | Rack 6 | Rack 7 | Rack 8 | Rack 9 | Rack 10 | Rack 11 | Rack 12 |
| *Absolute Humidity (%)* | *65* | *68* | *68* | 60 | 60 | 50 | 60 | 15 | 59 | 59 | 54 | 53 |
| *Inlet temperature (Celcius)* | 20.5 | 20.5 | 20.2 | 22.1 | 22 | 23.2 | 22 | 20.4 | 22.6 | 22.4 | 24.1 | 23.6 |
| *Power consumption (kW)* | 2.9 | 2.9 | 3.9 | 4.1 | 0.7 | 1 | 1.2 | 1.1 | 1.7 | 9.6 | 3.3 | 2.1 |
| ***Row B*** | | | | | | | | | | | | |
| *Rack* | Rack 1 | Rack 2 | Rack 3 | Rack 4 | Rack 5 | Rack 6 | Rack 7 | Rack 8 | Rack 9 | Rack 10 | Rack 11 | Rack 12 |
| *Absolute Humidity (%)* | *62* | *65* | *72* | *64* | *66* | 59 | 63 | 62 | 52 | 54 | 63 | 49 |
| *Inlet temperature (Celcius)* | 21.4 | 21 | 19.5 | 19.5 | 20.4 | 21.4 | 21.6 | 21 | 24.1 | 21.5 | 21.5 | 24.4 |
| *Power consumption (kW)* | 4.1 | 4.4 | 8.5 | 9.7 | 9 | 2.7 | 0 | 1.8 | 2.7 | 1.7 | 2.8 | 9.3 |
| ***Row C*** | | | | | | | | | | | | |
| *Rack* | Rack 1 | Rack 2 | Rack 3 | Rack 4 | Rack 5 | Rack 6 | Rack 7 | Rack 8 | Rack 9 | Rack 10 | Rack 11 | Rack 12 |
| *Absolute Humidity (%)* | *62* | *64* | *65* | 61 | *65* | 57 | 56 | 55 | 57 | 58 | 58 | 48 |
| *Inlet temperature (Celcius)* | 20.7 | 20.7 | 20.5 | 21.5 | 20.2 | 21.9 | 23.1 | 23.2 | 22.9 | 22.7 | 23 | *26* |
| *Power consumption (kW)* | 0.2 | 1.1 | 3 | 0.8 | 4 | 1.9 | 2 | 6.8 | 6.3 | 4.8 | 5.1 | 4.8 |

## 4. CONCLUSION

This paper discussed the cooling aspect of data center, the working principles and the close-coupled air direct expansion technology used for cooling. The infrastructure design of the data center must follow international standards and guidelines such as Uptime Institute tier classification or ASHRAE thermal guidelines to ensure the operational environment of IT equipment. Failure to maintain these recommended operating conditions can increase the risk of data loss and security breach, in addition to having a negative impact on the operation of IT equipment, resulting in a business's economic losses. We also discuss about energy efficiency and ways it can be improved for existing data center. On that basis, we conducted a case study of an existing data center in Hanoi starting with gathering all the available data to calculate the current KPI as well as simulate its condition to assess whether if it is operating as it is intended to with the same capacity when designing it and based on the ASHRAE's fourth edition of thermal guidelines, we deduce whether or not if the thermal numbers are aligned with the one we got from the CDF simulations. We then give a brief overview of the current situation of the data center, identify potential risk and give out recommendation for future works and further optimization. For this instance, we have concluded some results for the data center that we carried out the assessment that the current data center is not up the initial intent of being a Tier III classification for the Uptime Institute.

To analyze the design proposal optimally, CFD airflow analysis was performed to estimate the temperature distribution, air flow route, pressure, and airflow velocity, as well as evaluate the optimum conditions of air distribution for the data center. The results showed that the current cooling. We found that the cooling system is currently meeting the required statistics for Tier III classification. However, due to space restrictions, we recommended to downscale the IT load to that 70% of the original design due to the lack of space for the HAC areas. Overall, the data center we conducted the research on haven't met the requirements for tier III classification as intended but there are rooms to be improved and, in both cooling, and power aspects that can further optimize the data center to ensure stable and around the clock operations.

***ACKNOWLEDGMENT***

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