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Free Cooling Investigation of SEECS Data Center

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Abstract

A major portion of energy consumption in data centers is attributed to data racks and HVAC equipment. An excellent alternative energy saving method is to utilize the environmental conditions to our benefit in the form of free cooling. In this study, the free cooling potential of Islamabad has been determined using the dry-bulb temperatures and humidity conditions by using meteorology data of the past sixteen years. This data is then used to optimize energy efficiency of the data center at the School of Electrical Engineering and Computer Sciences (SEECS), National University of Sciences and Technology (NUST), Pakistan. Using the load data obtained from detailed analysis of SEECS data center, it has been determined that significant savings in energy through free cooling can be achieved during the months of December, January, and February.

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Keywords: *Data center, HVAC system, meteorology data, free cooling, energy efficiency*

1. Introduction

A data center can generally be defined as a dedicated space which houses high performance computers, storage servers, communication racks, and a host of other information technology (IT) equipment. These centers form the base from where digital data can be managed, processed and exchanged [1]. Although highly effective in data management, a major downside of these data centers is the large amount of energy consumption. A typical data server consumes about 30 kW of power and with the ominous introduction of ultra-dense computing architectures in the next few years; this power consumption is projected to increase to as much as 70 kW [2]. The number of racks in a building can vary depending upon the nature of operational use, but there can be hundreds, and in some cases even thousands of racks in a building, all of which amounts to an extremely high rate of energy consumption.

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According to a report published in 2007 [3], buildings, housing data centers can be as much as 40 percent more energy intensive as compared to normal buildings [3]. Between 2005 and 2010, the energy consumption by data centers increased by 36 percent in the Unites States, which made nearly two percent of the total energy consumption in the country [4]. A major chunk of energy consumed by the data centers is accounted by the cooling systems, mainly computer room air conditioning units (CRACs). In fact, nearly 40 percent of the power consumption is due to the operation of CRACs [5, 6]. The main objective of researchers was therefore to introduce ways through which this huge energy consumption can be reduced to a significant extent. In this regard, free cooling represents an ideal choice. In this approach, ambient air has been used to cool data center equipment. The potential for this cooling depends on atmospheric parameters, such as dry-bulb temperature and humidity. In more holistic terms, this potential depends on the capability of ventilation [7]. It is pertinent to note that free cooling does not involve mechanical cooling equipment; in fact, it complements these equipment and increases the energy efficiency.

There are a number of studies in literature which indicate that considerable energy savings can be made by using this technique. Bulut et al. [8] organized the bin weather data for different cities of Turkey. This bin data can be used to extract free cooling potential of the atmosphere. He then used this bin data concept to study the free-cooling potential in domestic environment [9]. This bin data model quickly became the most commonly used concept to investigate the free-cooling potential of any given environment. Papakostas et al. [10] further worked on this concept and developed the data for 38 Greek cities. Ghiaus et al. [7] studied the potential for free cooling in domestic environment using a method centered on the indoor-outdoor temperature differences. Dovrtel et al. [11] studied the free-cooling method with variable flow rate control, which incorporated weather forecasts into a control system. Budaiwi et al. [12] investigated the energy performance of an economizer cycle under three different climatic conditions and delivered significant results with regard to energy-saving potential. This paper implements the free cooling concept to Islamabad's environment.

The aim of this study is to propose a methodology to optimize energy consumption in the SEECS lab, by removing its sole dependence from mechanical cooling equipment. The authors used the bin data concept for free cooling. This data, spanning over the course of last 16 years, was collected from the Meteorology Department of Pakistan. Free cooling was achieved keeping dry bulb temperature and humidity as base parameters with detailed analysis performed with the help of ASHRAE psychrometric charts and softwares, such as ELITE, CHVAC, and AUTOCAD. An inside temperature range of 18 to 27°C was defined and with the help of ASHRAE recommended envelopes, it was shown that this range can be applied safely till an outisde temperature of as much as 27°C. In general, free cooling concept incorporates the usage of air side economizers. However, in this study, an effort has been made to achieve free cooling solely dependent on the outisde ambient temperature. It is for this reason, the ideal months for complete free cooling have been highlighted.

2. SEECS data centre cooling infrastructure

There are a total of 14 server racks inside the SEECS data center, with capacities of 6 kW per rack. Additionally, there are four communication racks, with a maximum capacity of 4 kW. For cooling, two CRAC units are installed with a capacity of 20.64 TR each. They have two compressors each, having capacities of 10.32 TR. The detailed infrastructure of the data center is shown in Fig. 1. Raised flooring is used in this data center so that the supply air can be fed through the floor via perforated tiles and return air sucked by the CRAC units freely. Currently, there is no provision of hot and cold isling.

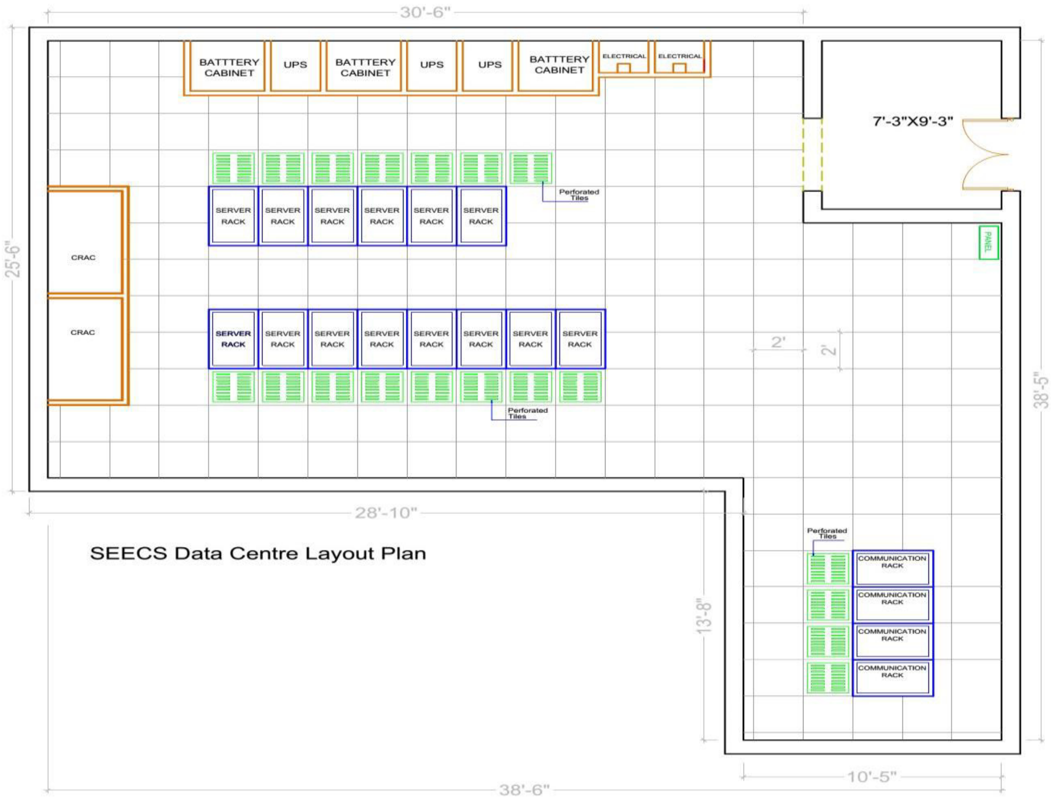

Fig. 1. Layout of SEECS Data Center

3. Methodology and Discussion

The total cooling load of this facility is 35.07 TR (420,822.16 Btu/hr. In this study, the authors focused solely on the ambient air temperature for free cooling, which could only be achieved in winter months (December-February) since the ambient temperature is low. For these months specifically, we can subtract the space load from the total load, which then reduces to 32.74 TR (392,946.16 Btu/hr). Thus we have to design a free cooling system which can remove 392,946.16 Btu/hr from the SEECS data center. The first step towards doing so is to estimate the amount of supply air which can remove that much Btu/hr. The air flow rate can be calculated using Eqn. (1).

$$Q = [H_s / 1.08 \times (T_R - T_S)] \qquad (1)$$

Where Q is the air flow in cubic feet per minute (cfm), H_S is the total room sensible heat gain, BTU per hr, T_R is the room dry bulb temperature in °F, and T_S is the supply air temperature in ºF.

With the value of H_s fixed at 392,946.16 Btu/hr, the only variable which will affect the value of cfm is (T_R – T_S) or ΔT. This differential between the inside and ambient temperature is 20°F as per ASHRAE Standard 62.2 [14]. In a data center environment, there is high sensible heat ratio. Whenever this ratio is above 0.85, the recommended value for ΔT is 17°F.

The ASHRAE environmental classes for data center [15] are shown in Fig. 2. These classes define the recommended values of tempertaure and humidity for IT equipment. The classes from A1 to A4 have been developed by different manufacturers after testing their individual IT equipment. The extremeties of all these classes are suitable for testing, however, these conditons are not feasible for prolonged operation of IT equipment. It is for this reason that ASHRAE has defined a recommended envelope, within which the equipment will perform safely even at both the extremeties, be it for tempertaure or humidity. The temperature range of this envelope starts from 64.4°F till 80.6°F (18 - 27°C). Similiarly, the relative humidity (RH) range is 28 – 60% RH. At this point, the authors have recommended room conditions for free cooling. When ΔT is 20°F, the value of cfm is 18,192, whereas at 17°F it comes out to be 21,402 cfm. For free cooling design at T_R of 80.6°F (27°C), a supply air temperature T_S of 63.60 °F (17.56°C) is required as shown in Table 1. Till the time, the ambient air tempertaure is equal to this value of T_S or below, hundred percent free cooling can be achieved inside the SEECS data centre. In case, the outside temperature falls below 63.60 °F (17.56°C) and a temperature of 80.6 °F (27°C) has to be mainatined inside the room, dampers placed at the fan suction and exhaust ducts have to be used as shown in Fig. 3. These dampers, actuated by temperature sensors, ensure the proportionate mixing of the cold inlet air and the hot exhaust, so as to maintain the value of T_S at 63.60 °F (17.56°C). Similarly if T_R of 64.4 °F (18°C) is to be maintained, a supply air temperature T_S of 47.4°F (8.56°C) is required.

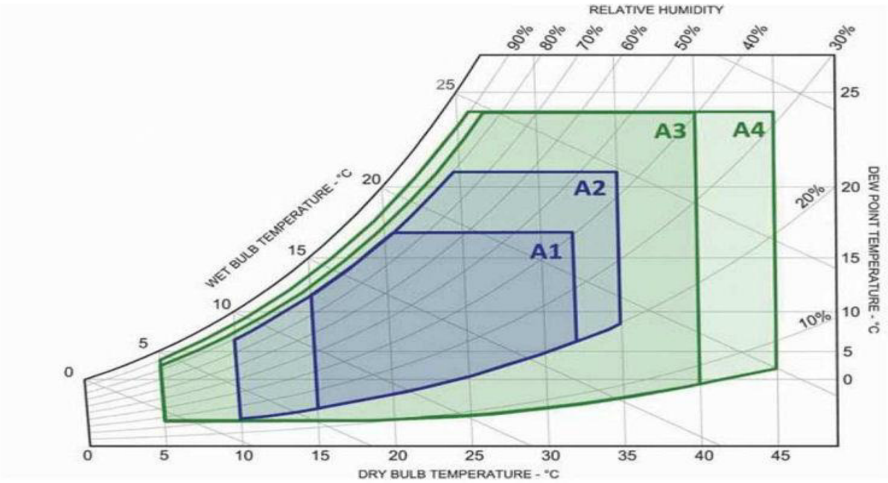

Fig. 2. Environmental classes for data centers

Table 1. Design conditions for free cooling

			T_R		T_S			
S. No	**H_S**	**Conversion Constant**	**^{0}F**	**^{0}C**	**^{0}F**	**^{0}C**	**Q (cfm)**	**ΔT (^{0}F)**
1	392,946.00	1.08	64.40	18.00	47.40	8.56	21,402	17.00
2	392,946.00	1.08	80.60	27.00	63.60	17.56	21,402	17.00

After determining the required cfm, fan selection is made using the NICOTRA Fan Selection software. A fan of 5350 cfm was selected at 0.787 inch of (Water Column) WC (196 Pa). This high value of fan static is kept to accommadate the pressure drop across the filters. The power consumed by a single fan is 0.867 kW. A total of four fans are required to achieve the total required cfm (21,402), as shown in Table 1. The total power consumed by four fans is 3.47 kW.

4. Bin data

Under normal circumstances, bin data is an hourly collection of environmental parameters like, dry-bulb, humidity and wet-bulb temperature, etc. [13]. In this study, the data is obtained from the Meteorology Department of Pakistan. The 16-year data spanning over 1996-2011 provides information at specific times of the day at 0300, 0900 and 1200 hrs GMT (0800, 1400 and 1700 hrs PST). The data, once organized in the required format, provided a starting point, and is arranged in daily, monthly, yearly and 16 yearly formats. Fig.4 shows the mean air temperature variation in Islamabad for 16 years. The figure shows that a temperature of 17.56°C is achievable in the months of December, January, and February. Hence, these are the months in which complete free cooling can be achieved. The exact number of bin values which occurred in each month is shown in Fig. 5. It is evident that maximum temperature bin values for December, January, and February lie under the 17.56°C barrier. Similarly, Fig. 6 shows the relative humidity bin values, most of which fall under the range of 28 – 60% RH for these three months.

5. Results

The analysis of free cooling potential of SEECS data centre at NUST, Islamabad has been carried using bin data concept. It is found that there is a significiant energy saving potential is available during the months of December, January and February. Free cooling can also be achieved during other months, however it would only be partial and falls out of scope of this study. According to the present layout, two CRAC units, with a total power consumption of 80 kW, have been installed in the SEECS lab to remove 392,946.16 Btu/hr (115.16 kW). This results in a very low coefficient of performance (COP). This value of COP however can be significantly increased by using free cooling. The comparison between the COP for the mechanical cooling system already installed in the SEEECS data centre and the proposed free cooling system has been shown in Table 2. The COP improvement in the case of free cooling is evident from the table. Also, under the proposed free cooling configuration, the amount of input power required can be reduced drastically, which would result in significant energy savings. A cost analysis was done based on this and has been highlighted in Table 3. It can be seen that by using free cooling nearly 3.3 million Pakistani Rupees can be saved in electricity bills during the months of December, January and February. It is pertinent to mention that this energy saving potential has been achieved for a very small data centre with limited IT equipment. There is room for much more energy saving if the data centre under focus is larger, and if partial free cooling is also considered.

Table 2. COP comparison

S.No	Description	Input (kW)	Output (kW)	COP
1	To remove 392,946.16 Btu/hr or 32.75 TR (115.16 kW) by CRAC Unit	80	115.16	1.44
2	Fresh Air Fans (when ΔT is 17°F) required cfm is 21,219, so we need 4 Fans	3.47	115.16	33.21

6. Conclusion

Free cooling is an extremely effective method of designing energy efficient buildings, especially data centers. In this study, the energy efficiency of SEECS data center has been enhanced by using the free cooling concept during the months of December, January and February. Temperature and humidity bin data for Islamabad has been used to define the recommended operational envelopes for free cooling, and an estimate of likely cost savings and increase in efficiency has been presented.

Table 3. COP comparison

S.No	Mechanical Cooling (kW/h)	Free Cooling (kW/h)	Energy Conserved (kW/h)	Energy Conserved per day (kW)	Energy Conserved per month (kWh)	Energy Conserved for 3 months (kWh)	Price for Commercial unit (1 kW/h)	Amount saved per day (PKR)	Amount saved for 3 month (PKR)
1	80	3.47	76.53	1,837	55,102	165,305	20	36,734	3,306,096

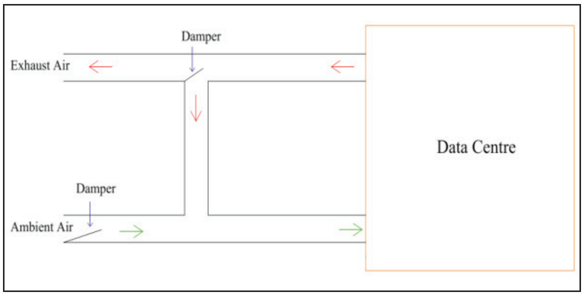

Fig. 3. Schematic of Free Cooling Supply Air Configuration

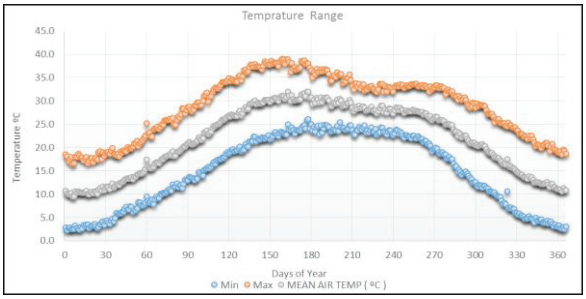

Fig. 4. Variation of Extreme and Mean Temperatures for 16 years

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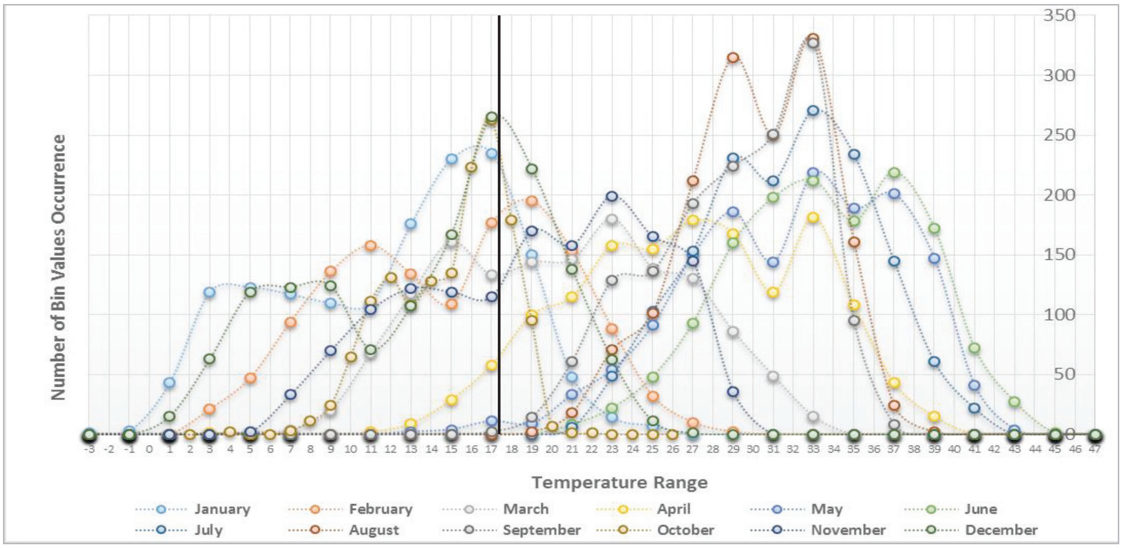

Fig. 5. Monthly Dry Bulb Temperature Bin Values for 16 Years

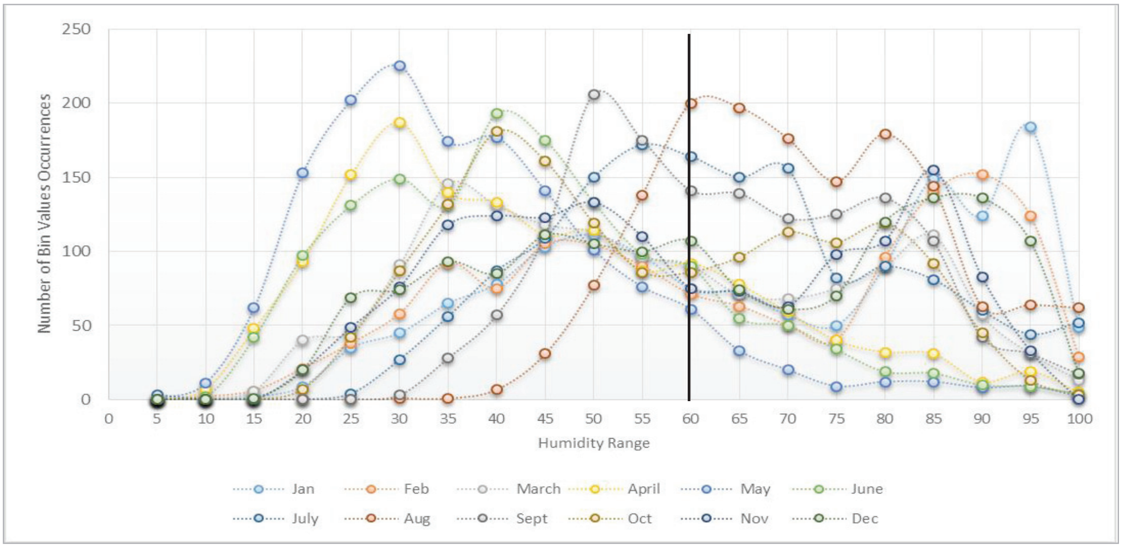

Fig. 6. Monthly Relative Humidity Bin Values for 16 Years