How can we use machine learning decision making models to control the Direct Air Free Cooling solution in Datacenters located in tropical climatic zones based on meteorological data analysis?

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INTRODUCTION

In the recent years, the cloud computing energy demand in terms of the establishment and maintenance of large datacenters has been increasing exponentially. This energy usage has a noticeable effect on the environmental sustainability due to an increase in the associated carbon footprint. Green cloud computing initiatives are being implemented in the datacenters to ensure sustainable maintenance and future growth of these data centers. Among these initiatives, cooling is identified as one of the improvement areas to reduce energy consumption. It is one of the most important auxiliary components in a data center that occupies a considerable part of the overall datacenter's power consumption . It also effects the reliability and efficiency of the IT infrastructure of the data centers.

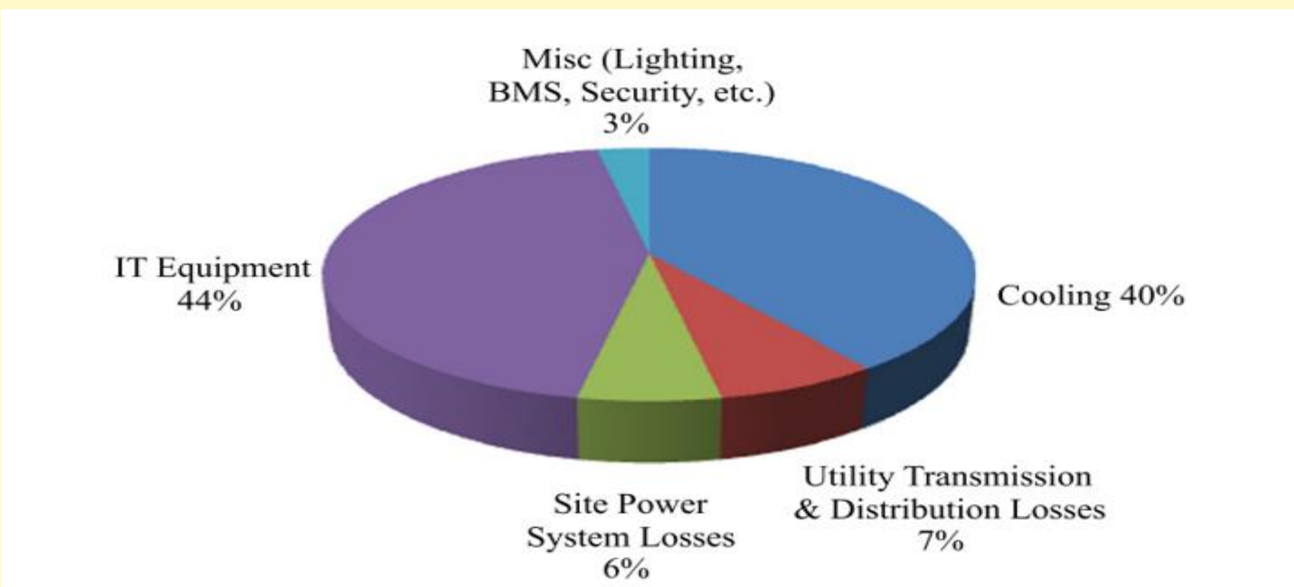

Fig.1: Datacenter Energy Consumption Distribution [6]

Direct air free cooling [8] is one of the emerging green techniques in which the ambient temperature of the air surrounding the datacenter is used for the cooling requirements of the datacenter equipment. Employing this solution will greatly reduce the energy consumed by the data centers and will aid in sustainable future growth. Also, it is a simple solution to implement. But the changes in the surrounding temperatures and climatic conditions will have impact on the performance of this system in the data centers established in different climatic zones throughout the world.

In the case of tropical zones, the ambient temperatures and relative humidity are comparatively high, and a precise control system is needed to employ the solution without which there is a possible risk of damage to the data center equipment resulting in their reduced efficiency and lifetime [9]. As part of this research, a predictive model that guides the control system to switch between in-house cooling and free cooling modes will be created. Random Forest Decision tree and Deep Reinforced Learning based algorithms will be used on historical meteorological data to create a decision supporting system model that will be handling the live meteorological data to proactively guide the cooling systems in the datacenter.

OVERVIEW

The greening of data centers is being implemented using several data mining and machine learning approaches. Significant research is being carried out in the industry and academia for employing green technologies to limit the environmental impact of the datacenters. These are broadly categorized as follows.

Optimizing the Data Center operation:

This includes research that concentrates on reducing the energy consumption of the data centers by

- Controlling the operational parameters
- Smart scheduling of the IT equipment
- Optimizing the cooling control
- Consolidation techniques for servers and virtual machines

In one study, Deep Reinforcement Learning (DRL) is used to proactively consolidate the virtual machines [1] to maintain satisfactory levels of Power Usage Efficiency(PUE) and reduce the associated carbon footprint. A multi agent approach is adopted to further optimize this model to improve the performance of IT and Cooling components collectively[2].

Load dependent predictive scheduling mechanisms proposed in another study [3] explored different scheduling algorithms for switching and consolidating the IT equipment. Decision supporting systems(DSS) have also been proposed to control the server sprawl [4] and improve the server utilization rate. Similar machine learning centered concepts are used in implementing a DSS that can regulate the internal working conditions of the datacenter to ensure least possible power consumption while maintaining satisfactory levels of SLAs which used thermal profiling and hot-cold spot analysis of the data centers [5].

Implementation of Free Cooling Solutions:

The revisions in ASHRAE classes for datacenter in 2011 have further increased the operating thresholds of datacenter equipment in terms of the temperature, relative humidity, dew point temperature and other relevant factors[6] as shown in the following figure.

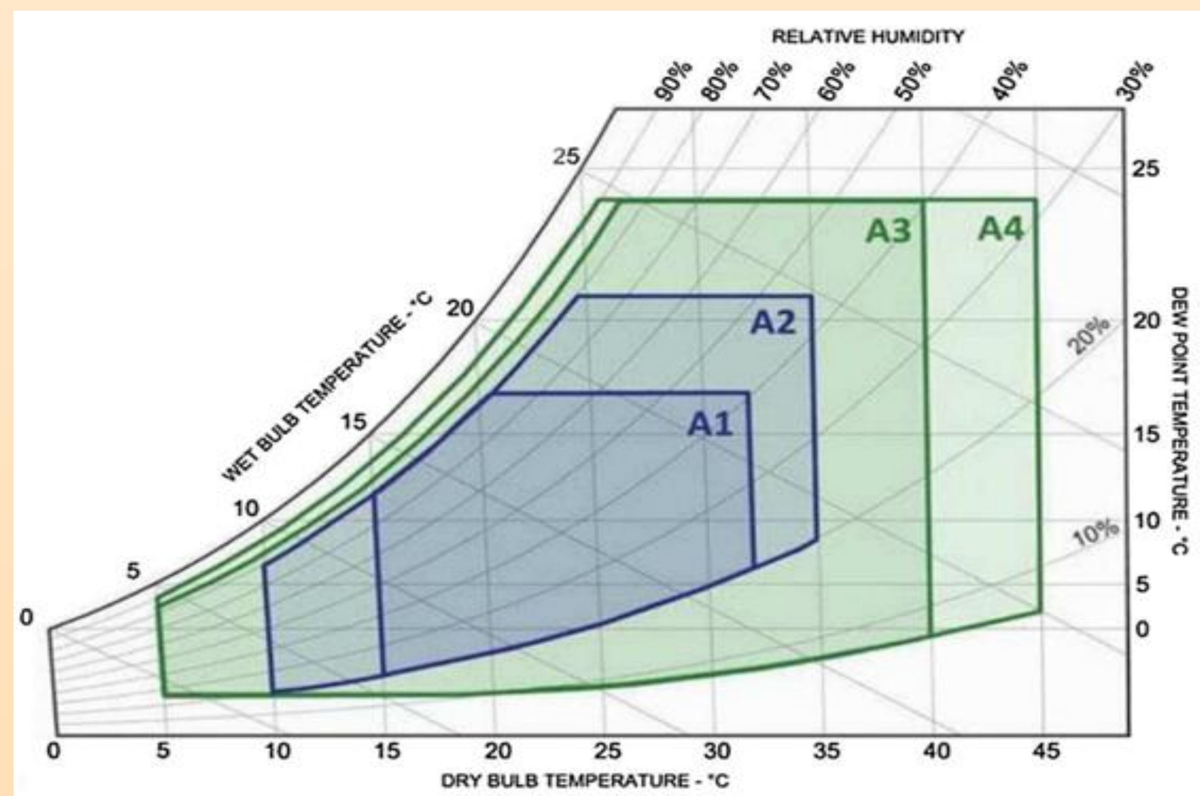

Figure 2: ASHRAE classes for Datacenter Economizers [6]

This paved a way for the implementation of the natural free cooling economizer cycles in the datacenters bypassing or supporting the traditional chiller plants. Recent research presented significant power savings by using natural side free cooling in different climatic regions of the world [7]. Direct air side free cooling has been found to be a simpler and more efficient form of air side economizers.

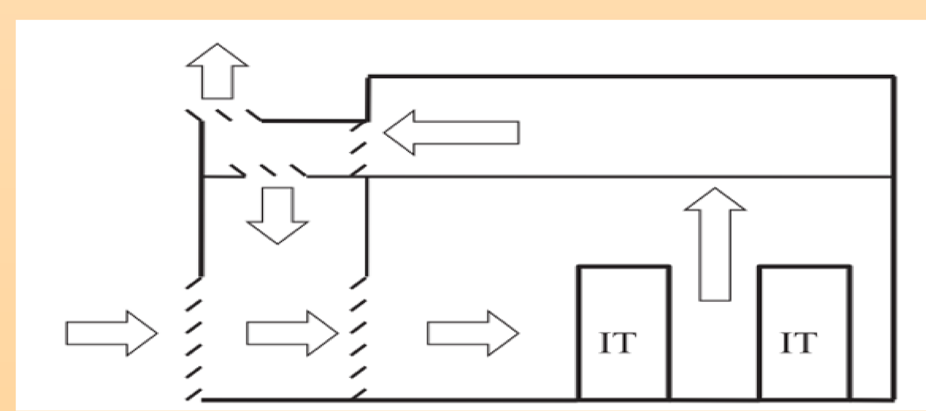

Figure 3 : Direct Air Free Cooling Schematic [8]

Although the operating thresholds for temperature and relative humidity have been relaxed in the A3 and A4 ASHRAE classes, sufficient and proactive control is needed for the reliable functioning of the direct air free cooling system. Many studies proposed the implementation of direct air free cooling that works independently or in parallel to a thermal storage[8] during off peak hours or a conventional cooling solutions like chiller plants to ensure reliability with focus on cost and power savings. A prognostic approach is discussed in the research[9] to implement the direct air free cooling solution. The tropical climatic zones pose drastic changes in temperature and relative humidity levels during different times of a day in a year. Predictive weather control by increased ventilation during the nighttime is suggested in data centers in tropical zones[10]. But with the help of a reliable DSS, the direct air free cooling economizer cycle can be operated at different times of the day with proactive engagement of the conventional system as needed for maintaining the reliable and efficient operation of the datacenter.

METHODOLOGY

A datacenter in a relevant tropical climatic zone will be considered for the research. The local historical meteorological data will be collected from the monitoring agencies. The behavior of ambient temperature and relative humidity will be predicted based on various meteorological factors from the data collected [10]. The main advantage of considering the meteorological data in contrast to the weather data is that the former includes several features including temperature, dew point, wind speed, wind direction, cloud cover, cloud layer(s), ceiling height, visibility, weather, and precipitation amount. As a result, the model can be trained with additional features like dew point and precipitation amount that can be used to further reduce the energy consumption used in operating the humidification systems used on the intake.

This trained model will be fed with live meteorological data and the results will be used to operate a switching controller that changes the cooling modes between internal electricity based mechanical cooling and direct air based free cooling options proactively. For this purpose, Random Forest Decision tree coupled with Deep Reinforcement Learning will be considered.

The operation of the switching mechanism involving direct air free cooling and datacenter chiller based mechanical cooling methods is depicted in the following flowchart.

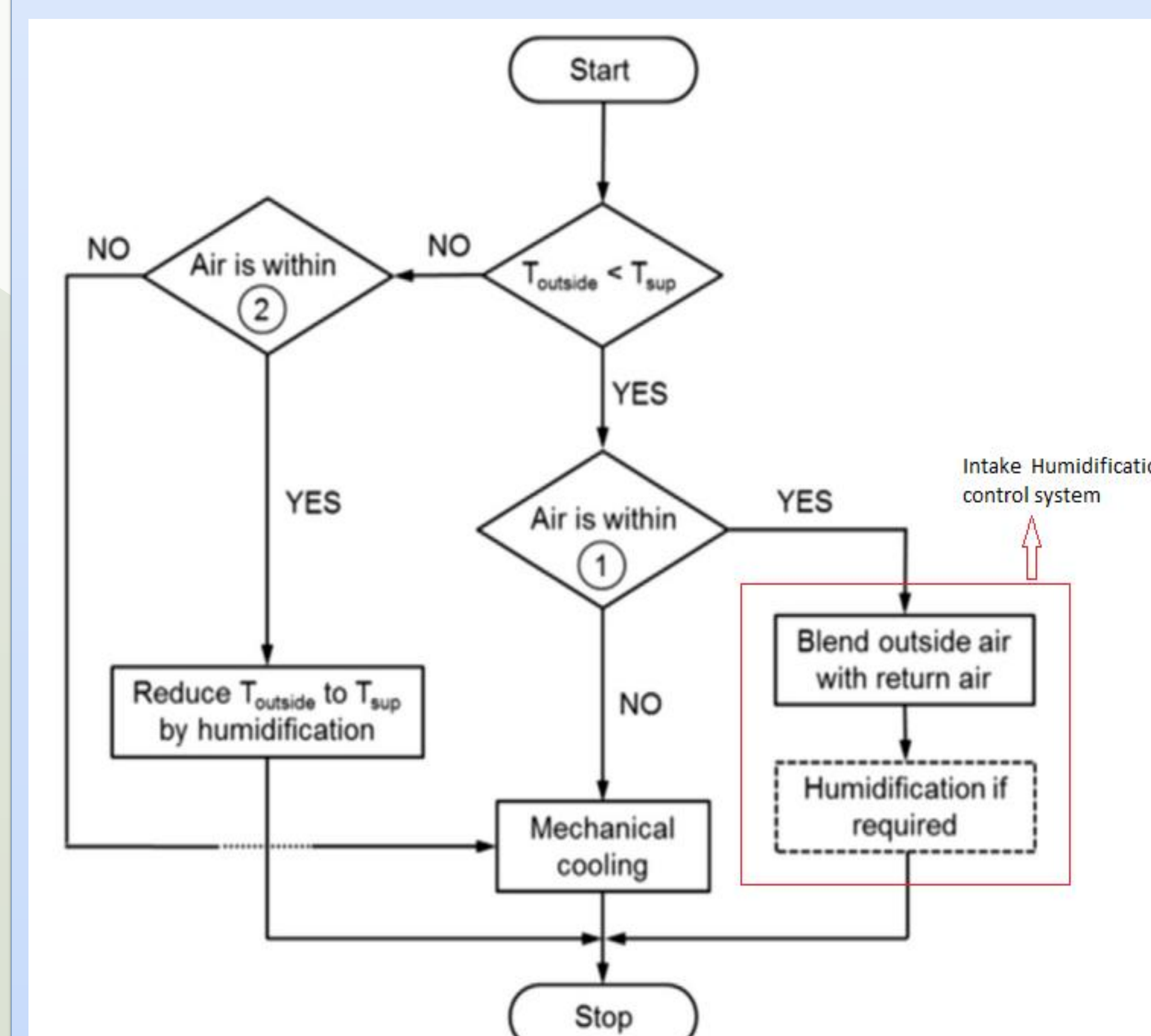

Figure 4: Direct Free Cooling Operational Flow

The Random Forest supervised learning algorithm will be used to create a regression analysis model which predicts the outside temperature($T_{outside}$) characteristics. The load based optimum supply temperature (T_{sup}) needed to maintain the reliable operation of the datacenter is determined using DRL [9]. These values will be compared, and appropriate cooling system is engaged by the switching mechanism. Maximum preference is given to the energy savings that can be realized using the economizer cycles while maintaining optimum performance and reliability. This model will also control the humidification and air blending components of the intake.

A virtual test bed will be simulated using Energy Plus simulator to analyze the maximum energy savings potential from the implementation of this model. For this consideration, the real-world thermal profiles and operating characteristics for an average server of ASHRAE level A3 in a tropical data center will be taken as reference. The test bed will be simulated with multiple machines of the reference type with varying load characteristics for the simulation.

ADVANTAGES AND FUTURE WORK

Advantages:

Datacenters in the tropical climatic zones in general record higher energy consumption for their cooling requirements due to the higher levels of overall ambient temperature and relative humidity. Implementing the direct air free cooling controls in these datacenters will have the following potential uses:

1. Optimal switching between the datacenter mechanical cooling and direct air free cooling options will assist in maintaining the reliability and efficiency of the datacenter operations.
2. Power Usage Efficiency of the datacenters can be optimized.
3. The direct air free cooling economizer cycles will reduce the cost of running the data centers.
4. Most importantly, the carbon footprint associated with the conventional chiller based mechanical cooling solution.

Future Work:

The proposed system is only limited to provide an efficient live feedback system that switches between the free cooling and mechanical cooling components. Future research will be concentrated on applying the machine learning principles to design a gradient system that can operate between both the free cooling and mechanical solutions with associated cold-hot spot identification related approach.

Also, this study can be further expanded to include other climatic zones with specific factors affecting the region. For example, datacenters prone to severe cold and humid climates should also have efficient control mechanisms that need to work in synchronous to the mechanical heating/cooling plants to maintain optimum operating conditions of the datacenters.

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