THE NEXT GENERATION GREEN DATA CENTER:MULTI-FACETAPPROACH TO REDUCE ENERGY CONSUMPTION OF MODERN SUPERCOMPUTERS

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Abstract—In recent years the technology is driven by large amount of data. In order to operate and store this data it is mandatory to build, design new data Centers as well as evolve the existing data centers with emerging technologies. There are various applications of data centers in different fields such as financial organizations, Telecommunication industry, Weather forecasting, E-commerce and many more. The principle concern which arise in case of data Center is extremely large power consumption. The primary reason for it is the heavy amount of heat generation during this process. The increase in energy cost has direct impact on operating cost of data center and is unavoidable. Hence it is mandatory to minimize the energy consumption in order to control the increasing operational cost.

Furthermore, data centers are significantly contributing to the growth in greenhouse gas emission. Hence while dealing with these arising problems, Data centers in India need to be designed in innovative way for improving energy efficiency and moving to the concept of Green Data Center" computing. This paper significantly studies one of the fastest supercomputer in India and analyze the various possibilities of energy saving by implementing advanced technologies and thereby saving running cost of data centers.

Keywords: Green Data Center (GDC), Energy Efficiency, Petabytes, Zetabytes.

Nowadays there is serious increase in energy consumption problem of data center. The increase in energy consumption causes increase in running cost of data centers as well as the large amount of waste heat generated creates the need to implement best cooling solutions in order to maintain the data center's performance. This project includes study of the structure of energy consumption of data center, including IT equipment, air conditioning, ventilation, UPS, lighting, etc. The primary focus of this research work is the energy consumption of air conditioning system in data center as it accounts for a larger proportion of the total energy consumption. Also second large power consuming section of data center is UPS system which is the backup supply system to provide 24/7 supply to whole data center. Further from the Energy-saving study point of view, this project work puts forward implementation ideas of new technologies in order to reduce running cost by minimizing energy consumption of data center.

RESEARCH OBJECTIVE

This Research comprises "Systematic Analysis of the existing system and identification of various possibilities to improve the energy efficiency of data center primarily focusing on cooling solutions and uninterruptible power supply with final comparison of the existing and future system". In more specific manner these objectives can be elaborated as follows:

1. To Study the Energy consumption pattern of HPC data centers.
2. To study the fastest Supercomputer of India power consumption pattern for improving efficiency by adopting advanced technologies.
3. Analyze and suggest to reduce energy consumption of modern supercomputers.

1. FUNDAMENTAL CONCEPTS OF DATA CENTER

The data center is a technical facility which forms dedicated space that includes IT operations and equipment such as servers, data storage devices, network devices along with critical systems including backup power supplies, air conditioning, and security systems.[1] This system as a whole performs the function of storing, processing, managing and distributing the digital information which is data. Data centers are the critical systems and plays vital role for expanding the capacities to store large amount of data in petabytes.

TYPES OF DATA CENTERS

There are mainly two types of data centers which are Internet data center(IDC) and Enterprise data center. In case of Internet Data centers, service providers constructs them as well as operate them. IDC's are also called as co-location managed Data center.[2] Enterprise Data centers supports many different functions in different application such as the n-tier, web services, and grid computing, it is mainly because of the complexity of the data held in Data centers.

DATA CENTER TIERS

In the designing stage of the data center, redundancy is the vital factor of consideration. The concept of redundancy lies in the availability of another duplicate set of components as a backup when one component fails to operate.[3] This system design which provides the alternative way makes the system more reliable and robust. Based upon redundancy levels, Data centers are categorized into four Tier levels. Tier I Data Center has no redundant capacity components i.e. there is no backup plan if one of the component fails to operate. It comprises of single path of non-redundant power distribution which operates the IT equipment. Tier II Data Center has redundant capacity components which operates when that typical component fails to operate. It also has single non-redundant power distribution path serving the IT equipment. Tier III Data Center system design comprises of redundant capacity components as well as multiple distribution paths operating the IT equipment.3 In this case, only one distribution path is active at a time for serving the computer equipment. The key feature of this system is dual-powered IT equipment which are fully compatible with the utility's power distribution architecture. [4]Tier IV Data Center has redundant capacity systems along with multiple distribution paths which simultaneously serves the IT equipment. This system is capable of facing any type of fault occurrence without failing. This function is achieved through electrical, storage and distribution networks.

ARCHITECTURE OF DATA CENTER

The direction of power flow for data center from transformer to IT equipment takes place in the following manner. Since the momentary outage of power can cause severe loss to the organization, there exists Uninterruptible Power Supply (UPS) units which acts as a battery backup to prevent the damage to the IT equipment.

Figure 1 Typical Data center power consumption architecture

The utility power at high voltage which is stepped down by transformer is first supplied to UPS unit. In the UPS, the double conversion of power takes place. Firstly the power is converted from AC to DC to charge the batteries and then again output power from the batteries is then converted back from DC to AC before leaving the UPS. [5]The output Power from the UPS enters into the Power Distribution Unit (PDU), which supplies power directly to the IT equipment in the racks. This is the basic idea for the power consumption architecture of data center.

POWER FLOW DIAGRAM:

Data center power delivery system provides backup power, regulates voltage, and makes necessary alternating current/direct current (AC/DC) conversions. The diagram shows the scheme of power flow of data center from the substation to the IT equipment.

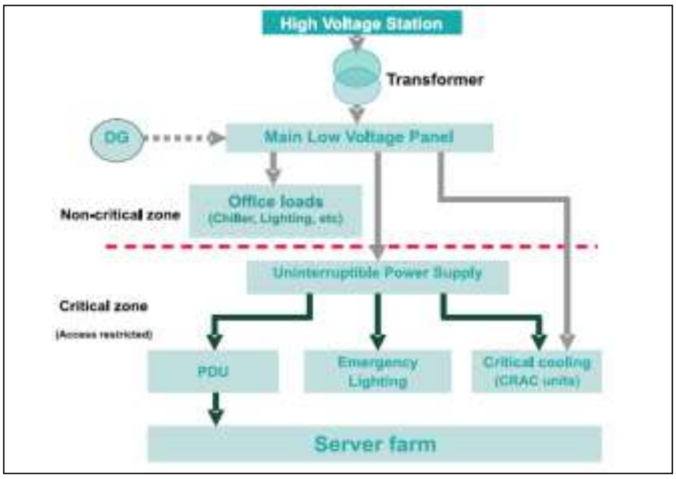

Figure 2 Power Flow in a Data Center

The power from the transformer is first supplied to an Uninterruptible Power Supply (UPS) unit. The UPS acts as a battery backup to forestall the IT instrumentality from experiencing power disruptions. A fleeting disruption in power might cause vast loss to the organization.. In the UPS the conversion of power from AC to DC takes place in order to charge the batteries. Power from the batteries is then reconverted from DC to AC before leaving the UPS.[6] Power departure the UPS enters an Power Distribution Unit (PDU), that sends power on to the IT instrumentation within the racks.

PRATYUSH- THE FASTEST SUPERCOMPUTERS IN INDIA

The Indian Institute of Tropical Meteorology (IITM) is the research institute based in Pune, with the primary focus on weather forecasting, climate monitoring, detecting earthquakes and specially monsoon predictions in India. "Aditya" and "Pratyush" are the largest computational capacities of India which are located at IITM.31 for solving the high resolution dynamic equations for climate monitoring and weather predictions more accurately, these supercomputers perform the vital role and provide common facilities for all Ministry of Earth Science institutions. [7] Following are some important features of "Pratyush"

1. Pratyush and Aditya are the supercomputers established at Indian Institute. of Tropical Meteorology (IITM), Pune.
2. "Pratyush" is installed at IITM, Pune in December 2017 and inaugurated on 8th January 2018.
3. Pratyush, the fastest supercomputer in India is having maximum speed of 4 PetaFlop.
4. The present data center PUE value is 1.2
5. The Total power consumption of Pratyush, the fastest supercomputer of India is approximately 1.4 Megawatts peak (IT Load).
6. It is the first multi-PetaFlops supercomputer ever built in India.ver built in India.
7. Pratyush and Aditya are used in the fields of weather forecasting and climate monitoring in India. It helps the country to make better forecasts in terms of Monsoon, fishing, air quality, extreme events like Tsunami, cyclones, earthquakes, lightning and other natural calamities such as floods, droughts etc
8. The current total IT load and other service load under this HPC unit is about 500 kilowatts.
9. India is the fourth country in the globe to have a High Performance Computing facility dedicated for weather and climate research after Japan, the United States and the United Kingdom.

The primary usage of "Pratyush" are as follows: The high performance computing system at "Pratyush" uses various numerical models in order to perform following tasks.

1. To generate best weather forecasts in terms of accuracy and before the forecasts Period.
2. To give very High operational forecasts of about 3km at regional scale and 12km at global scale.
3. To give fastest Tsunami alert in Asia pacific region.
4. To give official warning to potential fishing zones.
5. To monitor air quality continuously and give climate projections to citizens of India.

SYSTEM OVERVIEW

The Electrical system details of the data center are mentioned below. The high performance computing data center of at IITM, Pune draw power from utility at a voltage level of 22KV. The system is made highly redundant by installing the diesel generators for backing up the utility power feed. The series of switches on the utility and generator feed provides the redundancy to each equipment in the data center. The utility power at the high voltage of 22KV is firstly stepped down to 433V by transformer of rating 2.5MVA which is of delta-wye type step down transformer. The power is then passed through automatic transfer switches(ATS). The function of ATS is to sense that whether required amount of power from utility is coming or not. This sensing is necessary during power outages or power failures. During the interruption of utility power, the ATS switch sends signal to the diesel generators(DG) to turn on. Also the generators requires sufficient some amount of time to turn on completely in order to provide stable level of power at the output. In such a case, the time between the power failure and the fully power delivering generators, is compensated by using the standby power supply of UPS.[8] The UPS systems provides the standby power. This standby power is delivered through batteries of high capacities for about 15 minutes and more. Batteries stores energy to bridge the gap between the point of utility power failure and the starting point of fully powered generator.

Figure 3 System Overview of Data Center

After restoration of utility power back again, the Automatic Transfer Switch, switches back to the utility power feed and shut down the backup generators. The UPS systems are then recharged again through energy storage facilities. The output power from the UPS is given to the power distribution units(PDU). These PDU's again transform the voltage from 433 volts to 415 volts or 230 volts depending upon the requirement of data center equipment and also protects them through isolation transformer from high voltages.

The schematic of the cooling system of the HPC data center is as shown in the figure.

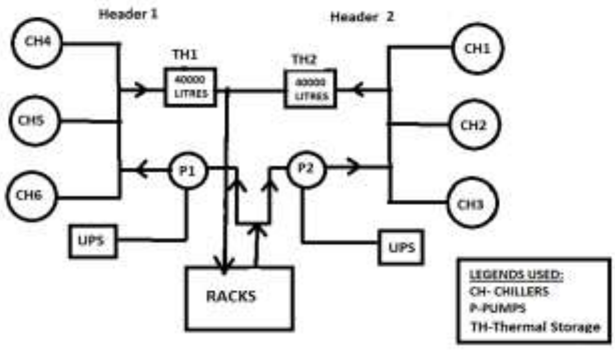

Figure 4 Schematic of chiller plant

Due to continuous operation of Data centers, it generates a large amount of heat. Hence it is necessary to remove this heat. For this purpose, we require cooling system. These cooling systems consume considerable amount of electricity. The cooling system employed at the "Pratyush" data center is of air cooled water chilled type. There are 2 number of thermal storage tanks each having capacity of 40000 liters for the storage of the water required for thermal backup. These thermal storage tanks gives backup supply of water for 30 minutes. There are 6 number of chillers each of 200TR capacity. TR is the unit for capacity of chillers which is known as ton of refrigeration and 1TR is equivalent to 3.5KW of cooling. Out of 6 chillers, the 3 are kept on standby mode and remaining 3 are in working condition.(N+N mode of operation).There are 2 pumps connected to the thermal storage tanks. The pumps have variable frequency drive system to control their operation which makes their operation more reliable. The continuity of power supply for pumps is maintained by installing utility UPS on each pump. The capacity of UPS systems of capacity 80KVA each dedicated specially for pumps. When power supply failure occurs, pumps will get turned on by UPS. These UPS system is having backup time of 15 minutes each. These pumps will then suck water from thermal storage and supply it for 30 minutes. This chilled water stored in thermal storage is supplied to racks. Hence there will be continuous supply of water for cooling purpose without any interruption. The water used is filtered water for better performance of cooling system. The quality of water is maintained by using the water softening system and automatic dozing system which performs various tests on water for checking its hardness and adding chemicals to maintain its purity .The installed chiller at this data center is of Inverter-screw chiller type. which makes the system more efficient than conventional chiller system. Inverter Screw chiller system maintains smooth operation and consumes low power at any operating condition. The cooling system works efficiently and continuously to maintain the temperature levels in the data center within prescribed limits.

The whole data center is highly secured with the help of security system. The continuous monitoring of all the parameters is done on Building management software(BMS) designed by Honeywell company. All the electrical data in each phase(R,Y,B) are continuously displayed on the digital screen as they are sensed by load meters instantaneously. Also there is facility to operate these systems individually through one click on BMS software which makes the system highly reliable to maintain and operate and also it displays the occurrence of fault immediately. Also for the safety of personnel inside the data center, there are various systems which detects the fire and gives alarm to the operators in the data center. For fire alarm system there is color code for indicating the

Figure 5 Color Code Status for Fire Alarm System

Intensity of the Event	Color Code	Legend
Normal	Green	G
Active	Red	R
Trouble	Yellow	Y
Starting	White	W

intensity of the event. The legends used are indicated in the above table. Also there exists "Gas suppression system" in which 'NOVEC 1230' gas is used for extinguishing the fire. This gas is suppressed below the tiles. If fire gets detected, then this gas blows out and extinguishes the fire. With the Access control system(ACS), smart cards are used for door opening and closing for security reason. But in case of emergency, the operation is done automatically, through BMS software, in order to secure people in the building premises. Aspiration system is used to detect the _re at earliest stage which prevents further damage to the data center. Also the installed water leak detection system detects any water leakage and gives the alarm accordingly.

2. MULTI-FACET APPROACH FOR ENERGY SAVING IN DATA CENTER

There are various opportunities for energy improvement in data center. These best practices can be adopted in various Data centers for improving energy efficiency levels.

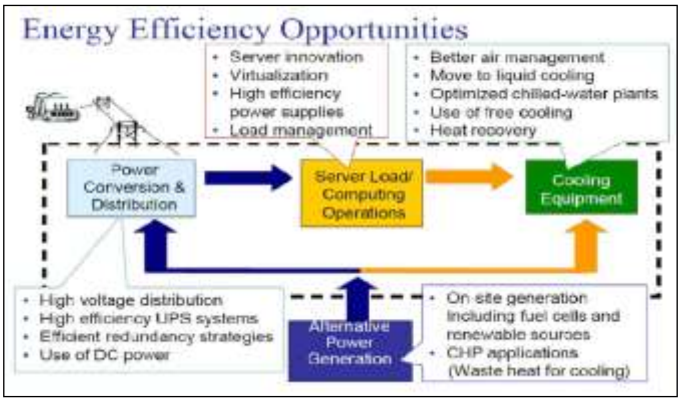

Figure 6 Energy efficiency opportunities in data centers

ENERGY SAVING OPPORTUNITIES IN ELECTRICAL SYSTEMS

i. The various possibilities for energy saving in electrical system are as follows: Typically, an UPS system has maximum efficiency at 75-80% loading When loading is less than 40-45%, the efficiency reduces drastically. It is recommended that the UPS loading should be maintained at more than 40%.

ii. By installing an Energy Optimizer which will sense the load demand continuously and controls the operation of the number of UPSs at any point of time and also maintains optimum loading on all UPS.

iii By employing the latest models of energy efficient transformers which can offer better efficiency levels than conventional transformers, will ensure that transformer faces optimal load for which its efficiency is higher.

iv Energy Efficiency through lowering of KVA intake can be effectively achieved through mitigation of harmonics by deploying a host of Parallel-connected harmonic filters.

v Research shows that more than 95 percent of utility outages last just a few seconds, so using a flywheel as a complement to batteries during brief power interruptions can save data center floor space and lower maintenance costs, while also extending the life of your lead-acid batteries by reducing how often you use them.

ENERGY SAVING OPPORTUNITIES BY INTEGRATION OF RENEWABLE ENERGY SOURCE TO SUPPLY DATA CENTER

Following are the key benefits of integrating renewable energy sources such as solar to power the data center.

i. These power sources are environment friendly since it is non polluting
ii. It is having very stable cost overall in comparison to the extreme volatility of power generated through fossil fuels also it helps us to reduce carbon footprints.[9]
iii. Although it is having high initial investment cost but operational cost after that is negligible.
iv. Efficiency of solar powered data center is higher because it has fewer conversions in the several components that are included in the line, such as the UPS and the battery.
v. Solar powered DC system is more reliable with very low risk of failure.

ENERGY SAVING OPPORTUNITIES IN COOLING SYSTEMS

The process of cooling used has a major impact on the energy efficiency of the datacenter. The Hot aisle/Cold aisle configuration is the latest system and is more energy efficient in compared to the conventional room cooling system. Following are the various ways for energy saving in cooling system.

i. First way for energy saving in cooling system can be achieved by increasing the Chilled Water Supply Temperature (CHWST) Set point: The chilled water supply temperature has a direct impact on the operating efficiency of the chiller. As a rule of thumb, chiller efficiency improves by 1% for every 1 degree Fahrenheit increase in the evaporator-leaving water temperature, all other factors held constant.[10]

ii. By integrating water-side economizer in chilled water plants can be another approach for energy saving. It is a heat exchanger (HX) in series with the chiller. During periods of low wet bulb temperature (often at night), the cooling towers can produce water temperatures low enough to pre-cool the chilled water returning from the facility, effectively removing a portion of the load from the energy-intensive chillers.

iii. Free cooling offers an additional level of redundancy by providing a non-compressor cooling solution for certain times of the year.

iv. By implementing variable condenser cooling water flow can result in more efficient operation. The standard procedure for operating water-cooled chillers is to maintain constant condenser water (CW) flow and a constant temperature of water entering the condenser, referred as condenser cooling water temperature (CCWT). Reducing the condenser water flow will reduce pumping energy consumption.[11] However, reducing the condenser water flow would increase the condensing temperature, causing the chiller to operate inefficiently. The lower condenser cooling water temperature will reduce the chiller condensing temperature resulting in efficient operation.

v. Evaporative-cooled chillers are essentially water-cooled chillers in a package. The system has a condenser, water, sump and pump, etc., all as integral parts of the chiller. The hot gaseous refrigerant is condensed by the water which flows through the condenser tubes. It facilitates the condensing temperature to be at ambient wet bulb temperature, as in water-cooled chiller. This system improves the operating efficiency of the chiller significantly as compared to an air cooled chiller and also reduces the power consumption of cooling water pumping system.

vi. Chillers are the major energy consumers in the cooling system. Most of the time the chillers are operated at part load conditions. The chiller performance degrades with time and operating conditions. Reduced chiller performance increases power consumption for a specific cooling load. By replacing old inefficient chillers with latest efficient chillers energy efficiency of chiller plant can be improved in significant manner.

vii. Presently, pumps are available with higher efficiencies, up to 85%. Appropriate high-efficiency pumps can be selected by matching their duty point to operating parameter values such as maximum head and flow requirements in the pumping system. Estimate the operating parameters such as maximum head and flow requirement and select a high efficient pump matching its duty point close to the operating values.

viii. Blade Room is a highly energy efficient modular data centre system, providing a scalable method of quickly developing data centers with an extremely low, proven

PUE. Tested and verified PUE of 1.13 is achievable, even with all electrical losses taken into account. Stand alone the Blade Room can achieve a PUE as low as 1.04.[12] The Blade Room modular data centre system dynamically matches cooling and airflow to actual IT demand. This means that PUE remains consistently low whether the data centre is partially or fully loaded with racks.PUE stays low at 100% to 15% occupancy levels. Allowing concurrent maintainability, a Blade Room modular data centre is built to Tier 3 levels of resilience as standard with dual distribution paths and N+1 components.

3. APPROACH I - UPS SYSTEM

Uninterruptible power supply system serves the dual purpose in data center. First to provide backup protection in case of power failure and secondly, it also protects the sensitive end load by isolating them from mains power supply.[13] UPS is the primary source which is linking the mains power supply and output load. Also UPS is performing the function of converting poor quality AC power to high quality power by removing spikes, sags and harmonic distortions. The UPS system at IITM data center is installed by Schneider Electric company which is of the double conversion type. The electrical configuration employed at 'Pratyush' data center is having 'N+1' redundancy.

CASE STUDY ANALYSIS:

The High performance computing datacenter "Pratyush" at IITM, Pune is a facility where availability of power supply for 24/7 hours for critical loads is mandatory. This goal is achieved by ensuring the availability of a continuous power supply to its IT equipment through UPS system. The UPS system installed is of "Double Conversion Type" having capacity of 1250KVA with input connection single as well as dual and with 4 level IGBT controlling technology by Schneider Electric company. There are 3 numbers of such systems installed. The efficiency of the UPS system varies with loading. From the UPS efficiency curve, the UPS system has maximum efficiency of 95% at 75% loading. From the further analysis point of view, we have monitored and stored the Total Non-IT load and Total IT load from 1st to 30th for the whole month of September. In order to calculate the power usage effectiveness it is required to observe the variation in Total Non-IT Load as well as the Total IT Load. From the monthly data analysis, the following details have observed for the month September. Average value of Total Load is observed to be 1316 Kilowatts. Average value of Total IT load is observed to be 1050 Kilowatts.

Specification	Unit(KW)
Total IT Load	1050
Total IT+Non IT Load	1316
Total Non IT Load	266

Figure 7 Electrical Loading Details

From the definition of Power Usage Effectiveness,

$$PUE = \frac{Total\ Facility\ Energy}{ITEquipmentEnergy}$$

Hence $PUE = \frac{1316}{1050}$

$$PUE = 1.25$$

DATA ANALYSIS OF PRESENT SYSTEM

For the effective cost analysis of double conversion type UPS system and Flywheel type UPS system it is required to calculate losses. The objective of this case study is to calculate the losses in terms of costing for next 5 years and thereby compare the present system with proposed system. For this case study the considered values of total IT load and Total load are average values of monthly data. These objectives can be achieved by following the two approaches:

ANALYTICAL APPROACH

Following calculations are done for analytical approach:

a) Static UPS Loss Calculations:

i. For 25% loading:
At 25% loading IT load will be = $1050 \times (25/100) = 262.5KW$
To support 1050KW IT load this UPS running at 76.21% efficiency and having constant Non-IT load 266KW must draw power =$(262.5 \times (100/76.21)) + 266 = 610KW$
Hence, Efficiency loss = $610 - 262.5 = 348\text{KW}$
Per year losses = $348\text{KW} \times 8760\text{hours} = 3047980\text{KW} - \text{hrs per year}$
For 5 years life cycle,$3047980 \times 5 = 15239902\text{KW} - \text{hrs}$
Approximate cost per Unit = 10 Rupees
Hence, For 5 years,
Losses costing =152399028 Rs.

ii. For 50% loading:
At 50% loading IT load will be = $1050 \times (50/100) = 525KW$
To support 1050KW IT load this UPS running at 85.06% efficiency and having constant Non-IT load of 266KW must draw power =$(525 \times (100/85.06)) + 266 = 883KW$
Hence, Efficiency loss = $883 - 525 = 358\text{KW}$
Per year losses = $358\text{KW} \times 8760\text{hours} = 3137931\text{KW} - \text{hrs per year}$
For 5 years life cycle,$3047980 \times 5 = 15689658\text{KW} - \text{hrs}$
Approximate cost per Unit = 10 Rupees
Hence, For 5 years,
Losses costing = 156896584 Rs.

iii. For 74% loading:
At 74% loading IT load will be = $1050 \times (74/100) = 777KW$
To support 1050KW IT load this UPS running at 88% efficiency and having constant Non-IT load 266KW must draw power $=(777 \times (100/88)) + 266 = 1149KW$
Hence, Efficiency loss = $1149 - 777 = 372\text{KW}$
Per year losses = $372\text{KW} \times 8760\text{hours} = 3258321\text{KW} - \text{hrs per year}$
For 5 years life cycle, $3258321 \times 5 = 16291609\text{KW} - \text{hrs}$
Approximate cost per Unit = 10 Rupees
Hence, For 5 years,
Losses costing = 162916090Rs.

iv. For 75% loading:
At 75% loading IT load will be = $1050 \times (75/100) = 787KW$
To support 1050KW IT load this UPS running at 88.83% efficiency and having constant Non-IT load 266KW must draw power $=(787 \times (100/88.83)) + 266 = 1152KW$
Hence, Efficiency loss = $1152 - 787 = 365\text{KW}$
Per year losses = $365\text{KW} \times 8760\text{hours} = 31974001\text{KW} - \text{hrs per year}$
For 5 years life cycle, $3197400 \times 5 = 15987000\text{KW} - \text{hrs}$
Approximate cost per Unit = 10 Rupees
Hence, For 5 years,
Losses costing = 159870000Rs.

v. For 100% loading:
At 100% loading IT load will be = $1050 \times (100/100) = 1050KW$
To support 1050KW IT load this UPS running at 95% efficiency and having constant Non-IT load 266KW must draw power $=(787 \times (100/95)) + 266 = 1371KW$
Hence, Efficiency loss = $1371 - 1050 = 321\text{KW}$
Per year losses = $321\text{KW} \times 8760\text{hours} = 2814265\text{KW} - \text{hrs per year}$
For 5 years life cycle, $2814265 \times 5 = 14071326\text{KW} - \text{hrs}$
Approximate cost per Unit = 10 Rupees
Hence, For 5 years,
Losses costing = 140713260Rs.

b) Flywheel UPS Loss Calculations:

i. For 25% loading:
At 25% loading IT load will be = $1050 \times (25/100) = 262.5KW$
To support 1050KW IT load this UPS running at 81.5% efficiency and having constant Non-IT load 266KW must draw power $=(262.5 \times (100/81.5)) + 266 = 588KW$
Hence, Efficiency loss = $588 - 262.5 = 325.5\text{KW}$
Per year losses = $325.5\text{KW} \times 8760\text{hours} = 2851380\text{KW} - \text{hrs per year}$
For 5 years life cycle, $2851380 \times 5 = 14256900\text{KW} - \text{hrs}$
Approximate cost per Unit = 10 Rupees
Hence, For 5 years,
Losses costing =142569000 Rs.

vi. For 50% loading:
At 50% loading IT load will be = $1050 \times (50/100) = 525KW$
To support 1050KW IT load this UPS running at 92.4% efficiency and having constant Non-IT load of 266KW must draw power $=(525 \times (100/85.06)) + 266 = 834KW$
Hence, Efficiency loss = $834 - 525 = 309\text{KW}$
Per year losses = $309\text{KW} \times 8760\text{hours} = 2708432\text{KW} - \text{hrs per year}$
For 5 years life cycle, $2708432 \times 5 = 13542163\text{KW} - \text{hrs}$
Approximate cost per Unit = 10 Rupees
Hence, For 5 years,
Losses costing = 135421636 Rs

vii. For 74% loading:
At 74% loading IT load will be = $1050 \times (74/100) = 777KW$
To support 1050KW IT load this UPS running at 94% efficiency and having constant Non-IT load 266KW must draw power $=(777 \times (100/94)) + 266 = 1092KW$
Hence, Efficiency loss = $1092 - 777 = 315\text{KW}$
Per year losses = $315\text{KW} \times 8760\text{hours} = 2764618\text{KW} - \text{hrs per year}$
For 5 years life cycle, $2764618 \times 5 = 13823093\text{KW} - \text{hrs}$
Approximate cost per Unit = 10 Rupees
Hence, For 5 years,
Losses costing = 138230936Rs.

viii. For 75% loading:
At 75% loading IT load will be = $1050 \times (75/100) = 787KW$
To support 1050KW IT load this UPS running at 75% efficiency and having constant Non-IT load 266KW must draw power $=(787 \times (100/75)) + 266 = 1097KW$
Hence, Efficiency loss = $1097 - 787 = 310\text{KW}$
Per year losses = $310\text{KW} \times 8760\text{hours} = 27646181\text{KW} - \text{hrs per year}$
For 5 years life cycle, $2764618 \times 5 = 13587677\text{KW} - \text{hrs}$
Approximate cost per Unit = 10 Rupees
Hence, For 5 years,
Losses costing = 135876778Rs.

ix. For 100% loading:
At 100% loading IT load will be = $1050 \times (100/100) = 1050KW$
To support 1050KW IT load this UPS running at 95.79% efficiency and having constant Non-IT load 266KW must draw power $=(787 \times (100/95.79)) + 266 = 1362KW$
Hence, Efficiency loss = $1362 - 1050 = 312\text{KW}$
Per year losses = $312\text{KW} \times 8760\text{hours} = 2733120\text{KW} - \text{hrs per year}$
For 5 years life cycle, $2233120 \times 5 = 13665600\text{KW} - \text{hrs}$

Approximate cost per Unit = 10 Rupees
Hence, For 5 years,
Losses costing = 13665600Rs

GRAPHICAL APPROACH

In this approach, the calculation of losses are calculated in terms of costing by using MATLAB software 2015 version

Table 1 Cost Analysis of Double Conversion Type UPS System

Sr No.	IT Load (%)	IT Load (KW)	UPS Efficiency (%)	Losses (Lakhs)
1	25	262.5	76.21	1523
2	50	525	85.06	1568
3	74	777	88	1629
4	75	787.5	88.83	1598
5	100	1050	95	1407

Table 2 Cost Analysis of Flywheel Type UPS System

Sr No.	IT Load (%)	IT Load (KW)	UPS Efficiency (%)	Losses (Lakhs)
1	25	262.5	81.5	1426
2	50	525	92.4	1354
3	74	777	94	1382
4	75	787.5	94.683	1358
5	100	1050	95.79	1397

In this software, these costing losses are plotted graphically against percentage loading of IT load.

GRAPHICAL RESULTS

After giving the required input data and running the program developed in "MATLAB" software,[14] graphical results shows the graph plot of losses in terms of costing in Lakhs rupees versus IT loading in percentage.

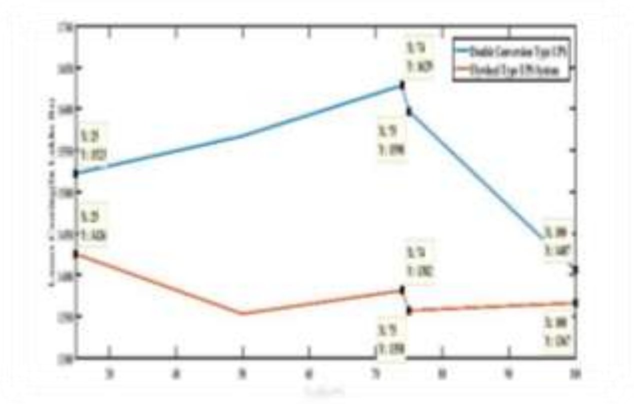

Figure 8 Comparative Analysis of Losses Vs Loading of Double Conversion and Flywheel Type UPS System

The color convention legends are as per the graph, i.e. blue for double conversion type and red for flywheel type UPS system. The visual difference in graph shows that there is so much difference in costing for both these types of UPS systems.

EXPECTED ENERGY SAVINGS

After getting the exact values of losses in terms of costing for specified loading, its necessary to compare the losses and to calculate the amount of energy we are saving i.e. nothing but the fact that how much losses we are able to minimize after implementation of flywheel UPS technology. After comparing both the systems and plotting the graph of difference in costing versus loading in percentage we get following graph. This graph shows the expected energy saving in terms of costing in Lakhs rupees at specified loading.

- At 25% loading we are saving 97 Lakhs rupees
- At 50% loading we are saving 214 Lakhs rupees
- At 74% loading we are saving 247 Lakhs rupees
- At 75% loading we are saving 240 Lakhs rupees
- At 100% loading we are saving 40 Lakhs rupees

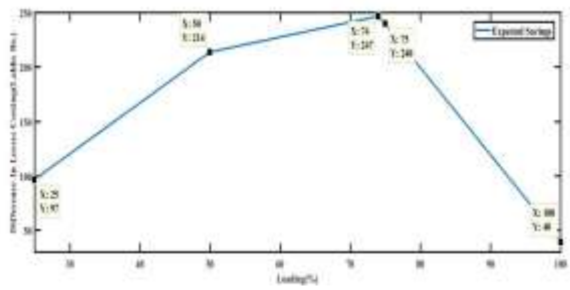

Figure 9 Graphical Analysis of Expected Energy Saving

The UPS efficiency curve of double conversion type UPS system at "Pratyush" data center shows that it runs at its maximum efficiency of about 95% at 74% of loading and at this percentage of loading of 74%, it is possible to save 240 Lakhs rupees in terms of costing of losses. This is the huge difference in terms of energy saving which reduces the overall operational cost of data center.

4. APPROACH II-SOLAR POWERED DATA CENTER

Energy efficiency is undoubtedly a watchword in the telecoms and data center industry. Many ICT companies now have corporate social responsibility (CSR) programs focused specifically on reducing their data centers carbon footprints and every data center operator wants to be able to promote the fact that their data center is green.

DIFFERENT WAYS TO USE SOLAR ENERGY FOR DATA CENTERS

Following are the 3 ways that can be implemented to use solar energy for data centers.

i. Buying solar power from a nearby utility

Some large data center operators, like Google, have created long monetary commitments for purchasing renewable energy from green energy suppliers within an equivalent grid regions as their data centers. Regardless of whether or not native utility firms will give the data centers entire power demand from renewable sources, it's actually a step within the right direction because it not solely reduces the data centers carbon footprint however additionally supports long investment in alternative energy generation by the utility company a win for all involved.

ii. Building a local solar farm as a partial energy source

Building a smaller, native solar farm as a dedicated partial energy supply will be a viable choice for a few data center operators. As the solar power made here is usually consumed directly within the data center, there's no need for extra battery storage or additional frequent battery replacement. This considerably improves the business case to make a neighborhood solar farm, and it improves however more in areas wherever either the value of grid power is high or the grid is unreliable, leading to vital use of expensive diesel gen-sets so as to stay the data center live. An interesting development here is that the introduction of DC-powered servers. This may eliminate the necessity to convert solar-generated DC power to the AC power employed by most servers these days and therefore cut back each initial cost still as on-going DC to AC power conversion losses within the system

iii. Building a local solar farm as the primary energy source

As mentioned above, accessible land for the installation of solar panels is probably going to be a major limiting issue even when establishing a neighborhood solar farm as a partial energy supply. This challenge then grows if it's to be used as the primary energy supply. In recent years, electrical device potency has improved considerably, however even in tropical conditions with excellent solar insolation you'd still want (roughly) a 39kW electrical device nearly 260 sqm to support one IT rack with a 5kW load. thus even for a comparatively little data center with solely ten racks, you'd want a region of 2,600 sqm only for solar panels. Even if the real estate was obtainable to put in a large enough solar array, solar energy is after all solely obtainable to be collected for a restricted range of hours per day (if in the slightest degree on cloudy days). For the remaining time the ability would want to be hold on in doubtless huge and intensely pricey battery banks a cost pill that the majority data center operators would merely not swallow. Added to the present, in typical data centers the battery is often kept in oat charge, which means on standby and used just for emergency backup functions. however batteries that are employed in solar applications are often charged and discharged. this can cut back their period of time and that they would wish to get replaced each 3 to 5 years counting on the kind of battery used associate operative expenditure issue to feature to the cost issue on top of it. However, there's associate exception a positive business case may be created for solar because the primary energy supply for remote small data centers in areas wherever there's no electricity grid and diesel power is that the solely choice. This rising market may be effectively served by hybrid solar energy systems (such as Flexenclosures eSite).[15]

iv. Integration of Solar power for Data Centres

On-site renewable energy systems are located on or adjacent to a facility where the energy is consumed. This section focuses on solar photovoltaic (PV) generation, the most flexible and fastest growing form of commercial on-site renewable energy. Mid scale (10 kW to 5000 kW) on-site wind generation installations are viable in select areas of the country but are far less common than on-site solar PV generation installations often due to logistical challenges. Other forms of renewable generation, such as geothermal, hydro power, and biomass, are typically impractical on-site generation options. Although the focus of this section is on-site solar PV generation, much of the information presented in this section is relevant to all forms of on-site renewable generation.

BENEFITS

Investing in on-site renewable energy projects is one of the most meaningful and direct ways to support renewable energy development. On-site renewable energy development is widely recognized to be beyond business-as-usual because

- on-site projects are directly enabled by the host organization
- on-site renewable energy is almost always more expensive than grid-sourced electricity.

An organization can claim environmental benefits associated with on-site renewable generation as long as it does not sell those benefits (in the form of RECs) to another party. Assuming the environmental benefits of the renewable energy are not sold, they will reduce an organizations Scope 1 emissions if the renewable generation reduces the fuel used for on-site conventional generation (e.g. gas-red generation) and Scope 2 emissions if the renewable generation displaces the consumption of grid electricity. Due to the high cost of developing on-site renewable energy systems, some organizations host a renewable generation system but sell the associated renewable attributes (RECs) as part of a third-party ownership financing model (e.g. power purchase agreement or lease structure). Organizations that sell all RECs produced by an on-site system can no longer claim any of the associated environmental benefits. After the REC component of on-site renewable generation has been sold, the remaining power component is known as null power. Null power should be assigned an average grid emissions factor, and thus is neither renewable nor emission-free. An organization that uses this null power cannot make the claim that a facility is powered by renewable energy or that the on-site renewable system decreases its carbon footprint. Even though the environmental attributes of an on-site project cannot be claimed after ownership of associated RECs is transferred to another entity, many organizations try to capture public relations benefits by claiming to host renewable energy systems. However, in October 2010 the Federal Trade Commission (FTC) proposed new guidelines that would prohibit this practice of claiming to host a renewable energy facility after selling the associated REC's. The FTC is expected to issue final guidance later in 2011. An organization may avoid this issue by either

1. Ensuring that its marketing claims highlight that that the RECs have been sold and that renewable energy is not used; or
2. Buying new RECs from the market to replace RECs sold. This latter, replacement REC, strategy would work well for an organization with an on-site solar PV system.

The organization could sell its solar RECs (SRECs), which may be worth several hundred dollars per MWh in some compliance markets, and then purchase a matching amount of voluntary RECs (e.g. Green-e National Any Technology RECs) for just a few dollars per MWh. Because the replacement REC strategy could potentially be perceived as misleading, organizations should carefully review the strategy and any potential implications before implementing this strategy. While solar PV generation is typically more expensive than other forms of renewable generation, costs are declining rapidly and local, state, and federal incentives can further reduce the net cost to a system owner. The cost of solar PV systems has declined markedly in the past few years due to cost reductions in photovoltaic (PV) modules, the most expensive component of a PV system.

5. APPROACH III-COOLING SYSTEM OF DATA CENTER

Data center heat removal is one in every of the foremost essential nevertheless least understood of all important IT environment processes. As the latest computing instrumentation becomes smaller and uses constant or maybe additional electricity than the instrumentation it replaced, additional heat is being generated in data centers. Precision cooling and heat rejection equipment is used to collect and transport this unwanted heat energy to the outside atmosphere. Cooling system in data center is one of the largest power consuming part, contributing more than 30% part of total energy consumption of data center. Hence it is necessary to implement new technology which will further reduce energy consumption of data center.[16] Since higher power demand results in increased internal heat rejection, thus its removal is a key requirement. The operating temperatures and relative humidity levels within Data Centre also needs to be closely controlled to ensure reliability in performance.

COOLING PROCESS IN A DATACENTER

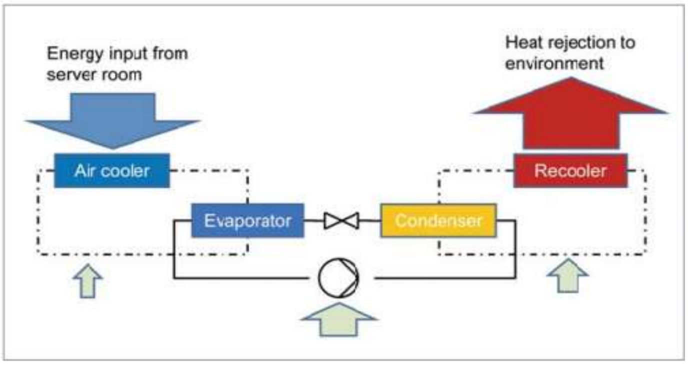

Figure 10 Data center cooling

The cooling process in a Datacenter is a closed loop system, i.e., the cold air supplied from the CRAC flows through the IT equipment and the hot air is re-circulated to the CRAC unit for removal of heat. Each server rack draws in cold air through the front of the rack and which gets heated as it circulates inside the servers and exits the rack from the rear side. Cold air is supplied to the server rack by the following two ways:

1. Conventional method - Room cooling technique
2. Contemporary method - Hot aisle/Cold aisle containment technique.

In the conventional room cooling technique, the temperature distribution in the room is determined by the inlet and outlet temperatures of different racks. The inlet temperature of a rack depends on the cold air supplied from the CRAC. The outlet temperature of a rack therefore depends on the inlet air temperature and the power consumption of that rack. The mixing of cold and hot air results in an increased distribution supply temperature and reduced return temperature to the crac which results in increase of load on the CRAC units. Figure shows the typical layout this technique. The racks are arranged such that the hot and cold sides are segregated to form an array of alternative Cold and Hot aisles. Air is being supplied through perforated floor tiles in the cold aisle. The inlets of each rack face the cold aisle and draws cold air coming out of the perforated floor tiles. This arrangement allows the hot air exiting from the rear side of the racks to return to the CRAC, thus minimizing the re-circulation of hot exhaust air from the rack back towards the inlets of other racks. Hence, it becomes very important to ensure that significant amount of Cold Air (Equivalent or more than the amount required by rack load) should be available in the front of the racks. As higher perforation levels of the rack door (up to 83%) enable better airflow, it is recommended to have as high perforation levels as possible. Designs of racks are available up to 83% perforation levels.

WATER CHILLED COOLING SYSTEM

Servers with critical duties will shutdown or fail when the inlet temperature and humidity levels rise above the specified standards, which typically are 20-25 degree Celsius and 40-55%. The temperature of high density equipment in Data centers can rise up to 40 degree Celsius in 3 minutes in the absence of CRAC units. [17]Therefore, failure-free operation of CRAC units is absolutely necessary to ensure reliable operation of the servers.

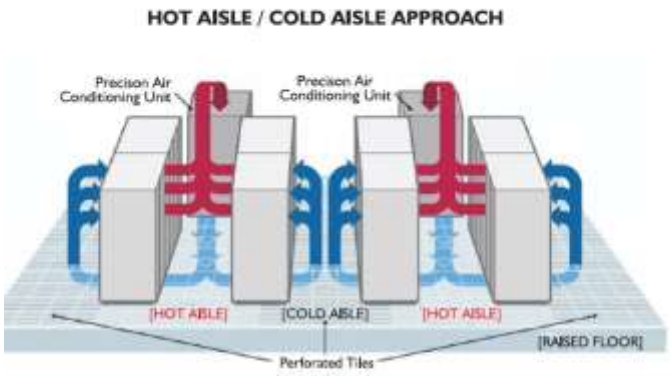

Figure 11 The raised floor of a Data center with the Hot aisle /Cold aisle setup

The cooling system has various components such as

1. Chiller units
2. Chilled water pumping system
3. Precision air conditioner unit
4. Air distribution system. Both the chilled water system and direct expansion type of cooling are used in Data centers.

CRITICAL COOLING CONFIGURATION AND ITS COMPONENTS

Precision Air Conditioner (PAC) units are essential in a Data center to maintain the equipment within the manufacturers specified temperature/humidity range. PAC is a high precision environment control system, specially designed to manage the cooling, heating ventilation requirements of mission critical applications.

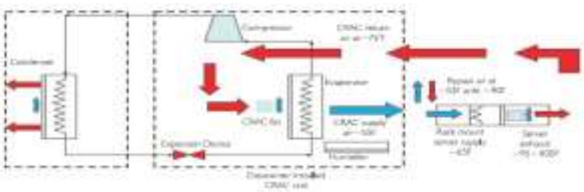

Figure 12 Typical Layout for direct expansion based precision cooling

Direct expansion (DX) system may be a compressor primarily based cooling system equipped with refrigerant as a cooling medium. The outdoor condenser unit used for heat rejection can be air/water cooled. The indoor and outdoor units are connected by means of pipes. The general schematic of the configuration is as shown below: CRACs are one of the most common cooling systems installed in upcoming Data centers. CRAC uses the direct expansion of refrigerant gases to remove heat inside the Data center and reject it to outdoor spaces. These systems generally encompasses a comparatively tiny (30 Tons wise capacity) compressor system and evaporator coil put in within the data center area, and a condensation unit installed outdoors to reject the energy from the space.

CHILLED WATER UNITS

Chilled water units are refrigerant less cooling units which uses chilled water as a cooling medium. An externally located chiller system supplies chilled water to the unit as per the cooling requirement of the Data center. The typical layout of the chilled water system is as shown in figure.

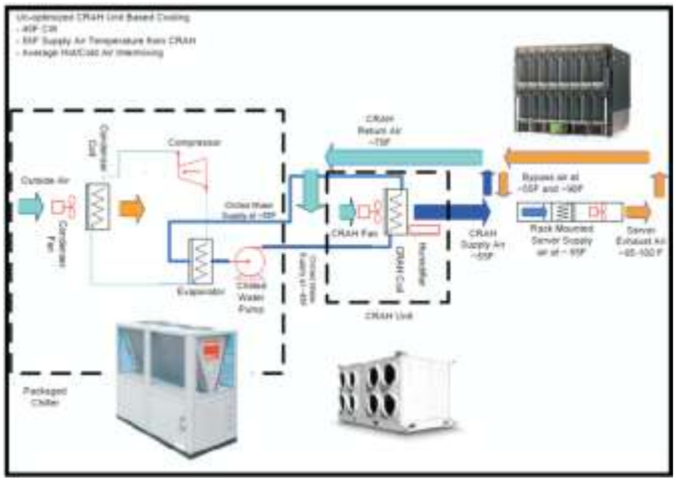

Figure 13 Typical Layout for chilled water based precision cooling

The chilled water-based CRAH units are the most commonly adopted system for Data Centers requiring large capacity cooling (i.e. 100-1000 tons).[18] The higher capacity also facilitates efficient energy usage in the compressor and fans.

DUAL FLUID UNITS

The dual fluid unit is a combination of direct expansion and chilled water unit. The chilled water units are connected to the external chiller system for the regular supply of chilled water. Such a combination unit gives advantage of power saving and redundancy.[19] The advantages of dual fluid units are as follows:

1. Lower fluid cost
2. No limitation to room size

These units also posses following limitations:

1. Water damage risk if a leak occurs

2. May require fluid treatment to prevent fouling

3. Limited overhead cooling options.

FUTURE TECHNOLOGY -DRY CHILLER COOLING SYSTEM DETAILS

In many cases, hybrid dry coolers are used as re-coolers. The resulting cooling water temperatures are much lower than those reached by dry coolers and thus make for better Energy Efficiency Ratio(EER) values for the refrigeration chiller.

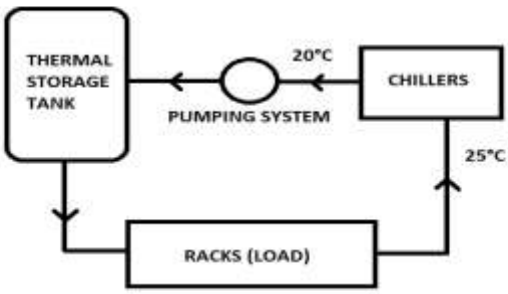

Figure 14 Block diagram of Dry chiller system

Furthermore, the hybrid cooler requires considerably less space and power. As compared to cooling towers, the annual water consumption is reduced by approx. 75 to 90% depending on the design. Further advantages are the guaranteed vapour-free operation, and the much lower noise level. Figure 12 shows for a simple block diagram of this system. Thermal storage is a technique of storing thermal energy in a reservoir for later use, and is an economical technique of accelerating plant capability while not adding chillers. Thermal storage offers 3 main advantages:

1. First, it takes advantage of the off-peak electric rates which are typically significantly lower.

2. Second, chilled water systems operate more efficiently when the outside air temperatures are lower.

3. Third, chilled water storage adds redundancy and can often substitute for one or more back up chillers.

It is a cost-effective alternative to additional mechanical cooling capability. Thermal storage is recommended predominantly to facilities larger than 10,000 sq. ft. Water storage is preferred over ice because water is simpler, cheaper and more reliable, although it requires more space. Use multiple tanks for system redundancy and emergency backup cooling potential. Thermal storage works, when power supply fails and supply chiller water to sensors up to 10 minutes. Dry chiller work on high temperatures for which the range is 25 degree centigrade inlet and 20 degree centigrade outlet temperature. Hence power required by dry chiller is less, since there is no compressor. Dry chiller consumes only 25% power. Hence if the system having capacity of 100TR consumes power of about 88KW then after installation of dry chiller it will consume only 22KW power. Hence huge amount of power can be saved by using dry chiller technology. The coolers run entirely dry, i. e. with convective heat exchange with the ambient air in the cold season or during partial load operation. Only when the required cold water temperature cannot be reached any more in dry operation, the wetting circuit is engaged automatically.[20] Thus, the application of the natural principle of evaporation makes the hybrid coolers extremely energy-efficient. Energy consumption is minimized by using axial fans thanks to axial fans with frequency-controlled speed control and energy efficiency class Eff1 drive motors.

FEATURES OF DRY CHILLER TECHNOLOGY

Figure 15 Hybrid Dry Cooler

1. The chilled water temperature is higher temperature. It is of the range of 18/25 degree centigrade. Conventional methods runs chiller at lower temperature. But since this method is running chillers at high temperature improves the capacity as well as reduces the total power consumption to cooling output.
2. The refrigerant used is of "R134a" which is non-toxic, non-flammable and non-corrosive. Also it has a boiling point of -15.34 degree Fahrenheit or -26.3 degree Celsius that makes it exist in gas form when exposed to environment and have high heat of vaporization.[21]

EXPECTED ENERGY SAVINGS

The power consumption of Compressor is about 70% to 80% of the total power consumption of chiller. So, in order to achieve the goal of reducing the power consumption of chiller, it is required to reduce the power consumption of compressor specifically. Since in proposed technology, the idea is replacing the compressor with dry chiller technology, it will result in 70% to 80% of energy saving. In addition to measures such as strictly separating cold and heat air within the server rooms, increasing the room temperature and using hybrid dry coolers for free cooling is an effective method to save energy in data centers. This methodology reduces the operative hours of energy intensive refrigeration chillers and exploits the natural and environmentally harmless principle of evaporation by means of hybrid cooling. With the air intake temperature of 27C suggested by ASHRAE, one may do without energy-intensive refrigeration chillers virtually throughout the whole year. As long as the refrigeration chiller is running, hybrid dry coolers will give terribly low cooling water temperatures, which improves the refrigeration chiller's EER and thus considerably reduces its power consumption.

6. CONCLUSION

Today the world of big data is moving towards fastest technologies in order to store, process and predicting the models based on this data. Due to its large size, Data centers are the mandatory systems in order to store this data. Data center Energy Efficiency is the interesting field of research area for future computational world. Energy efficiency improvement related research has made greater achievement into the energy field since data centers are consuming 2.5% of global power. The major focus of this work in on cooling system and UPS system of data center. This facilitated to develop, implement and analyze various technologies for energy improvement by analyzing the future energy savings and thereby reducing operating cost of data centers. Following conclusions can be drawn from this work. This paper primarily suggests various opportunities of energy saving in high performance computing data center. The suggested best practices can be adopted in existing or future data centers for improving energy efficiency levels in significant manner. The key factor of power management is covered in two major fields of data center which are UPS system and Cooling system. The analysis shows that the expected energy saving is 247 lakhs rupees in losses in terms of costing for rotary UPS system and this energy consumption reduces by 70% by installing dry chiller technology. Also. another approach for reducing energy consumption of data center is by integration of renewable energy source to supply power to the data center. By implementing this idea, the energy consumption will reduce by 12%. Suggested best practices can be implemented in existing and future data centers. The future scope of this work lies in the fact that, by employing these multi-facet approaches the data center will transform towards green data center.

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