Selection of Sensor Architecture and Design of Sensor Framework for Blade Server and Data Centre Cooling System

Mahendra Singh Thakur, and Dr M Madiajagan

***Abstract*—** This paper focuses on a dual stage cooling system which can be used in thermal management design for a uniform cooling process. It enhances the green revolution cooling for a Blade Data Centre and Server Room. The system will provide a most energy efficient cooling solution and can work more efficient with the hybrid cooling system. The first stage cooling incorporates the active perforated Peltier layer sandwich between two Blade units, which gives optimum cooling effect to the Blade Data Centre or a Server Room and the Sensor based second stage gives the uniform cooling distribution mechanism. The heated blade device is encompassed in a confined chamber for the uniform cooling that can be verified through Computational Fluid Dynamic (CFD) Modeling.

***Keywords*—**Blade Server, Energy, Peltier, Sensor, Thermal

I. Introduction

THE development of high performance CPU operating at higher speed, follow the Moore's law which states that "the number of transistors on a CPU would double every two years", which result in increased heat generation and needs efficient cooling method for heat rejection.

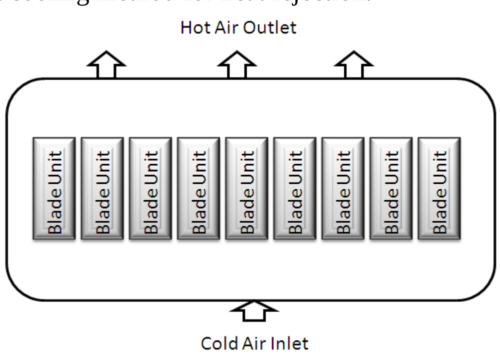

Fig. 1 Conventional Blade Cooling Architecture

A blade unit consists of CPU, RAM, HDD, Heat Sinks and associated electronic components, contribute to the generation of great amount of heat. The comparative analysis shows that even if a coolant is Gaseous, Liquid, Liquid submerged, or even use of Carbon Nano Tube mounts on electronic components, can reduce the temperature considerably for a large Data Centre or Server room but with a great cost and compromise with the nature. This considerable change in temperature is done by large amount of energy conversion by the huge consumption of either CFC or Hydro Carbons.

The Blade unit can be cooled by three common methods of heat transfer.

—Radiation
—Conduction and
—Convection

The Radiation cooling is the method in which heated Blade Unit is placed in natural ambient environment to radiate the heat until such a time its temperature becomes equals to the ambient environment. This method requires lot of time to cool down the Blade Unit thus making us to prefer other suitable methods.

Conduction cooling method comprises of heat sink, which is directly attached to the heated components. The adoption of heat sinks depends upon its size, material and the number of fins. The generated heat from the component is transferred to the surface of the heat sink and the surrounding cold air draws the heat away through the fins.

Convection cooling method gives best result compare to previous cooling methods due to the fact that the forced cold air moves over the different parts and components of the Blade Unit. A properly designed plenum for air to move across around the Blade Unit gives best efficiency of energy usage.

This research hypothesis will enumerate and enhance the optimum cooling as well as uniform cooling using Peltier based perforated Thermo Electric Cooling (TEC) Device and sensor based air circulator respectively. The main constituents of the design model in the first stage consist of Peltier Device based Smart Sensor cooler unit and the second stage is comprises of air circulator unit with electronic and mechanical sensor valve.

Mahendra Singh Thakur is with the BITS Pilani Dubai Campus Dubai International Academic City, Dubai (UAE). Phone: +97144200699(thakur@)dubai.bits-pilani.ac.in)

Dr M Madiajagan is with the BITS Pilani Dubai Campus, Dubai International Academic City, Dubai (UAE). Phone: +97144200699(madiajagan@)dubai.bits-pilani.ac.in)

II. Problem Formulation

DESIGN *CONSIDERATION*

The proposed design is based on the facts that the existing coolant can reduce the temperature only up to a certain limit. Requirements of uniform cooling as Computational Fluid Dynamics (CFD) indicate non uniform cooling to the existing system.

Rapid increase in temperature of electronic component and slow heat removal can affect the overall system performance and can shorten the operational life of the components. [1]

The control circuit to maintain the TEC device temperature above the ambient (room) temperature is required to prevent the humidity formation, otherwise TEC device may turns the temperature much below than 274K.

III. Design Methodology

The Solution to the problem statement is addressed below in the form of Stage 1 Smart Sensor Architecture, Stage 2 Air Circulator Sensor Architecture, and Thermal Resistance Model of the console Unit.

STAGE 1

Peltier Device— The Peltier device is a Thermo Electric Cooling (TEC) device and this is one of the important and main constituents of the design model in this paper. The Peltier Device is made up of series of the n-type and p-type semiconducting materials pallets sandwiched between two ceramic layers which has the properties of electrically insulator and thermally good conductor, having negative and positive Seeback coefficient respectively. When a sufficient potential difference provided to this semiconducting material the junction of dissimilar semiconducting material results in change in temperature and one junction become cold and other become hot this phenomenon makes one surface of Peltier hot and other surface cold enough. The surface of hot and cold can be altered by applying a reverse potential in certain conditions. The material used in making of Peltier device must have a higher Seeback coefficient for thermoelectric application. [2] The semiconducting materials are preferred choice, over other metals to be used in such devices, because it is having high Seeback coefficient as well as higher thermal to electrical conductivity and has steady and linear effect of physical signal conversion effect.

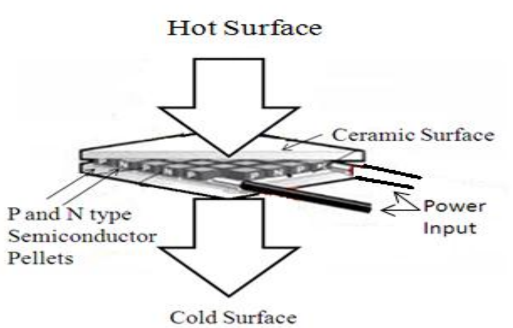

Fig. 2 Cross Sectional view of Peltier Device

The Thermoelectric figure of merit is a useful property to calculate good coolant materials. The empirical relationship of thermoelectric figure of merit is given by

$$zT = \frac{S^2\sigma}{\lambda}, \text{ or } = \frac{S^2}{\delta\lambda} \quad (1)$$

Where zT is Thermoelectric figure of merit, S is Seeback coefficient, σ is Electrical conductivity, δ is Electrical resistivity and λ is Total Thermal conductivity.

Available Alloy materials:

- Magnesium Silicide
- Silicon Germanium
- Lead Telluride
- Bismuth Telluride
- Bismuth Antimony

Temperature Range

- Minimum: 160 K
- Maximum: 523K can be extended up to 573K

Manufacturing Process

- Crystal Grown
- Sintering
- Thin film Deposition [3]

Smart Sensor— Normal sensor is a device or material that has activated energies like electrical, mechanical. These characteristics that changes with some physical phenomenon i.e. temperature, displacement, force. Sensor is a transducer which converts one form of energy to another one. Mostly the sensor are silicon based, silicon has steady and linear effect of physical signal conversion effect. Thermal Signals has the properties of Temperature, Temperature gradient, heat and different scientific effects on these properties are implemented e.g. Seebeck Effect, Peltier Effect, and Johnson Effect. [4]

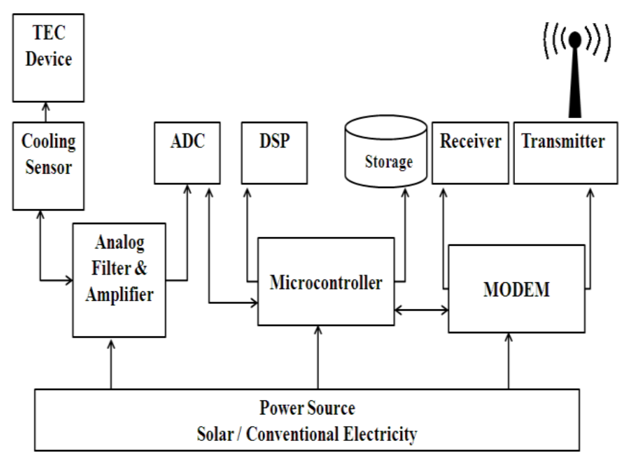

Fig.3 Smart Sensor Architecture

Compare to normal sensor a smart sensor has one or more normal sensors and it has electronic control circuitry. The smart sensor has microcontroller and processor which led to corrections for different undesirable sensor glitches which include input offset and span variation, non-linearity and cross-sensitivity. As these entire characteristic phenomenon are carried out in software, hence no additional hardware is required and thus calibration becomes an automatic electronic process control. [5]

A smart sensor is Active, Digital, Networked, Reconfigurable, Observable and is equipped with digital signal processing, microcontroller, and transceiver unit and which follows five main properties of Pervasive Computing i.e. Autonomous, iHCI, Intelligent, Distributed, and Context Aware. [6] The smart sensor embedded in the cooler unit and controls the flow of cold air and feed the air to the hot surface to provide optimum cooling of the Blade unit. This sensor has the ability to process the input data with power management functionality to take necessary action to reduce the unnecessary energy consumption of underutilized infrastructure. Periodically it transmits the temperature data in real time via network interface.

Following are the points which make Smart Sensor a real smart:

* Measured values are first preprocessed into meaningful quantities in Analog Filters and Amplified to a desired level and then converted into Digital form.
* Measured quantity is communicated two ways i.e. digital signals and with some communication protocols in Microcontroller.
* Automate the actions of primary circuits and sensors to take measurements.
* Remember calibration or predefined settings.
* A real time MODEM (Modulator-Demodulator) is attached with the smart sensor unit for wireless operations.

STAGE 2

Sensor Based Air Circulator --- Air circulator is the second stage of this paper. Blade Units are placed in a Rack are encompassed in sandwich manner along with the Smart TEC device Unit which then cool down nearby heated Blade Unit. The effective heat come out from the first Blade Unit will turn on the cooling process of the second Smart TEC device Unit .The hypothetical design is based on sensor based thermal valve to get a uniform cooling. This valve can be made either by NTC type or PTC type metallic alloys.

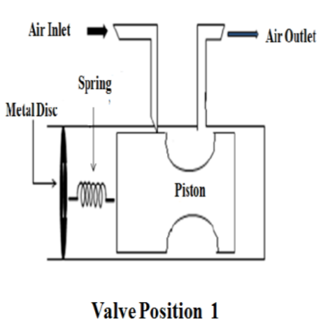

Fig.4 Open and Close position of Valve

The NTC type valve works on the principles of contraction of the metallic alloy spring, this spring is design to contract with predefined set point temperature, when the heat, above the set point temperature is touched down the opening surface of the valve, the spring starts squeezing linearly and it drags the mounted piston and provides passage to pass the heated air through vent pipe.

On the other hand PTC type works on the principles of metallic expansion. The PTC type spring is connected with piston mounted shaft, so when the temperature turns more than set point temperature, the spring expands linearly and opens the vent to pass the heated air through it.

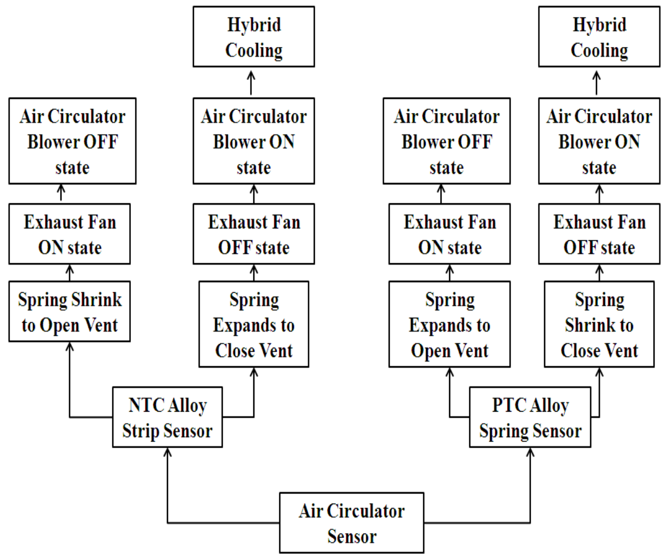

Fig. 5 Air Circulator Sensor Architecture

The overall system temperature, monitored and controlled by electronic temperature sensor to regulate the temperature and air flow for the condition less than and greater than the set point temperature. This sensor allows recirculation of air flow along with hybrid coolant till the temperature maintained to desired set point level.

Thermal Resistance Model---Heat transfer in the Blade Unit is an important factor to get higher efficiency of the system performance. Thermal Resistance Model is the fundamental and basic numerical analysis method of heat transfer. Static and dynamic are two models available for the numerical calculation of Thermal Resistance of the system in use. The static model of intuitive Convective Thermal Resistance Modeling is used to calculate Thermal Resistance of the system, by which the heat sink temperature can be estimated easily.

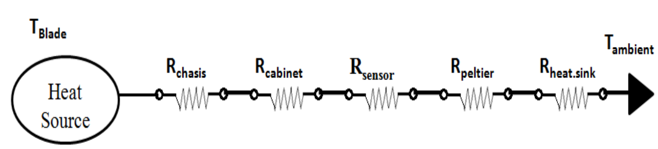

Fig. 6 Thermal Resistance Model of the Console Unit

Some useful empirical equations are used to calculate Convective Thermal Resistance of a material from a hot surface to the cold air flow.

Following useful empirical equations are used to calculate Convective Thermal Resistance of a material from a hot surface to the cold air flow.

According to Fourier Law of Thermal Conductivity,

$$q = \frac{\Delta T}{R_T} \qquad (2)$$

Where q is the *Rate* of Heat Conduction, T is Temperature Difference between two points, and R_T is Thermal Resistance of the material.

R_T , can be defined as

$$R_T = \frac{l}{kA} \tag{3}$$

Where l is the length of the material, k is the Thermal Conductivity, and A is the Effective area of the material.

By using the Convective heat transfer coefficient h, the Convective Thermal Resistance of a material equals to,

$$R_{convective} = \frac{1}{hA} \tag{4}$$

Therefore the heat Sink Temperature is given by

$$T_{HS} = T_{Air.in} + q(R_{Convective} + R_{Air.in}) \tag{5}$$

Where T_{HS} is the Temperature of Heat Sink, $T_{Air.in}$ is the Temperature of Cold Air, q is the Rate of Heat Conduction, $R_{Convective}$ is the Convective Thermal Resistance, and $R_{Air.in}$ is the Resistance of the Cold Air.

IV. Computational Analysis

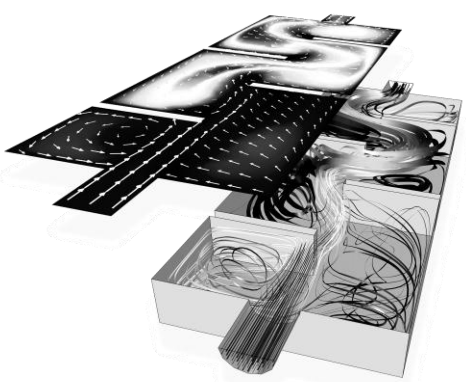

Fig. 7 CFD Image of Air Flow in a Heated Chamber

Computational analysis tools to formulate the cooling effect analysis of the Blade Unit in a Data Centre or a Server room are available in vide varieties. One of the standard Computational analysis tools is Computational Fluid Dynamics (CFD). CFD is interdisciplinary subject of Numerical Analysis, Fluid Dynamics, and Computer Science. It facilitate in the proposed paper in following manner,

It provides Vorticity and Stream Function for boundary conditions problem of Inlet and Outlet air flow and heat transfer.

It generates a fine grid cell to resolve the flow variables parameters.

It provides finite difference approximations of interior point of interest.

It is a Numerical (Discretization) analysis method for solving two dimensional and three dimensional Euler and Navier-Stokes equations.

It generates predictions of Thermal behavior of electronic system for effective cooling. [7]

V. Conclusion

The present study shows that proposed architecture of sandwich based Peltier cooling and sensor based Air Circulation Unit to reduce the energy consumption is notable hypothesis and simulation model can be implemented at laboratory level.

This concept is unique, modern and can withstand with present climate scenario and it is unexplored area till date in proposed manner.

The detailed study of literature survey shows that the system efficiency is lower than that of conventional compressed cooling system, but it can give a major contribution to reduce the considerable change in consumption of energy usage and adoption of better Thermal Management when it is compared with existing non uniform cooling system.

The overall performance of the system is done by Computational Fluid Dynamics (CFD) Analysis Tools. The outcome of data analysis will decide the change in design if it is deviate from the expected result.

References

[1] Banjerd Saengchandr, Nitin V. Afzulpurkar, “Novel Approach for Cooling Electronics Using a Combined Heat Pipe and Thermoelectric Module”, American Journal of Engineering and Applied Sciences, 2009, pp 603-610.

[2] Manoj Kumar Rawat, Himadri Chattopadhyay, Subhasis Neogi, “A Review on Developments of Thermoelectric Refrigeration and Air Conditioning Systems: A Novel Potential Green Refrigeration and Air Conditioning Technology”, Volume 3, ICERTSD 2013, pages 362-367, Feb 2013.

[3] John G. Stockholm, “Current state of Peltier cooling”, 16th International Conference on Thermoelectrics, Dresden, Germany, IEEE, 1997, 26-29 Aug., pp 37-46.

[4] Dayashankar Dubey, “SMART SENSORS”, [Database on the Internet], M.Tech.credit seminar report, IIT Bombay, submitted November 2002. Available from: https://www.ee.iitb.ac.in/~esgroup/es_mtech02_sem/es02_sem_rep_dubey.pdf

[5] Mahendra Singh Thakur, “Design & Development of a Smart Proximity Sensor System for Robotic Application”, [UG Project Work], Birla Institute of Technology & Science Pilani India.2012.

[6] Stefan Poslad. “Ubiquitous Computing: Smart Devices, Environments and Interactions”, John Wiley & Sons, Ltd. 2009, pp 1-40. http://dx.doi.org/10.1002/9780470779446.ch1

[7] Martin Pearse, “Modeling Methodology for Thermo-Electric Coolers in CFD”, Greenwich UK, IEEE, 2008, 1-4 Sept. pp 1171 -1174.