Immersion cooling as the next technology for data center cooling: A review

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Abstract. The utility of the world internet is on the rise as it is recorded that 46% of the world's population have become internet users who generates data traffic of up to 8 zettabytes daily. This increase has triggered the growth of data center infrastructure as processing, storage and communication system in the digital world. The data center itself has contributed 1.5% to the total world electricity consumption and this is expected to increase with time. The proportion of energy used in the data center covers 52% for information technology (IT) equipment, 38% for cooling and 10% for supporting devices. One of the problems faced by these centers over the years is the cooling of the information technology (IT) components. This paper describes a cooling model that has the potential to improve the efficiency of energy used in data centers. Numerous studies have been carried out and one of them involves the use of immersion cooling technique as it promises improvements in the energy efficiency of data centers, using dielectric fluids that have high heat capacity. Several types of fluid used in this method are identified and discussed in this paper.

1. Introduction

Modern industrial development has advanced for several hundred years, this has however come to the era of industrial revolution 4.0, characterized by the production of cyber physical system (CPS) [1]. This new technology raises a new trend about Big Data [2], which is a collection of data sets with large, varied and complex structures. Only about 5 Exa-bytes (1018 bytes) of data were made by humans until 2003. In 2012, digital data was expanded to 2.72 zettabytes (1021 bytes), which is estimated to double every two years, reaching around 8 zettabytes of data in 2015 [3]. This rise in the amount of data traffic also correlates with the increase in the number of world internet users, which according to data from the World Bank (2018), reached 46% of the world's total population in 2016 [4]. Digital data that is so fast, large and varied is influenced by several factors such as data science, social media and various kinds of web sites and web services [5]. The increase in the number of requests for data processing, data storage and digital communication has led to the development of big data infrastructure [6]. which is processed and stored in a data center [3]. Furthermore, data center is a facility consisting of a collection of servers, network devices, data storage apparatus and refrigeration units [7]. The energy consumed by data centers in the world continues to increase, in 2005, the electricity consumption reached 1% of total world electricity consumption, which rose to 1.5% in 2010, which is an increase of 33% from 2005. This is expected to rise five times more in 2025, according to the Japanese ministry of economy. The electricity
consumed by the data center itself is divided into several fields, these include, 52% for IT purposes, followed by a cooling system that reaches 38% as shown in figure 1. and other supporting equipment reaches 10% [8]. Relatively, cooling systems use a lot of electrical energy because most data centers operate with air conditioners. Therefore, adjustments to the cooling system is needed to improve the efficiency of electrical energy consumed, this will also reduce maintenance costs and electricity usage [9].

Figure 1. Electricity distribution in data center [8].

2. Method
The design of this study is a literature review. This paper, therefore, discusses types of immersion cooling and working fluids used therein from the results of research conducted on the cooling system in the various research area to be a consideration in developing subsequent research.

3. Results and discussion
This part describes in details, the methods of immersion cooling and their fluid type as they involve the use of liquid to cool the component either directly or indirectly. This research is needed to obtain sufficient information foundation for the development of immersion cooling as the next technology for cooling the data center. The development of the immersion cooling method and the selection of the right working fluid can be further research.

3.1. Immersion cooling methods
This technique has long been used in cooling several electronic component models, some of which have been recorded in several studies as in Table 1. it involves the direct immersion IT hardware in a non-conductive liquid, hence, heat generated from electronic device is directly transfer to cooling fluid [10].

| Type        | Utilization         |
|-------------|---------------------|
| Single-Phase| Solar cell [11]     |
|             | Transformer [12]    |
|             | IT Equipment [13-14]|
| Two-Phase   | Server [15-17]      |

3.1.1. Single-phase immersion cooling. Single-phase immersion cooling involves using coolants to exchange heat without any phase changes [16]. This method is safer because of this as this means there is no gas / vapor produced by the cooling system, hence, protecting the system from explosion due to excessive pressure. It is however, more flexible than air-cooling [17].
3.1.2. Two-phase immersion cooling. This cooling technique uses coolants to exchange heat when liquid-vapor phase change occurs [16], furthermore, vapors produced by the system when removing heat as shown in figure 3. Two-phase immersion cooling has the unique attributes of reducing environmental impact, simple design, increase power density up to 10 times, and affordable [18].

Figure 3. Two-phase immersion cooling [19].

3.2. Immersion cooling fluid
There are several types of fluid that can be used for cooling and the use of liquids is one of the most prominent and efficient as in table 2., with methods that can be directly or indirectly implemented [8]. For the direct method, the fluid must be non-conductive material because the fluid is in contact with electronic devices.

| Type      | Utilization               |
|-----------|---------------------------|
| Water     | Server [15, 20]           |
|           | 3D Stacked Dies [21]      |
|           | Solar Cell [22-23]        |
| Mineral Oil | Server [24, 13]           |
|           | Transformer [12]          |

3.2.1. Water. Water is conductive material, therefore it cannot be used directly for cooling electronic device. However, the cold plates and water-blocks are among the traditional materials that uses any conductive liquid such as water as shown in figure 4. Furthermore, recent research in this area typically focuses on the microchannel heat sinks and their efficiency enhancement [8].
3.2.2. *Mineral oil*. Mineral oils are used as the main liquid insulating medium because of their good electrical neutralizing and cooling properties. A number of these oils are used as cooling fluid as (Table 2.) as they provide a much higher capacity of heat transfer than air with the same volume [14]. This can be seen from the temperature difference between mineral oil and air cooling as shown in Figure 5.

![Figure 5. Temperature difference between air cooling and mineral oil cooling [24.]](image)

4. Conclusion
This review gives a superior technique to cool a data center utilizing the immersion cooling method, which is not a new technology as numerous researches have been recorded. For the data center however, more investigation is needed to exploit the capabilities of electronic devices and the effects this approach will have on them as well as its comprehensive impact on the environment. It was also observed that the use of immersion cooling significantly reduced the temperature of the component, which made the data center design simpler and further increased power density.

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