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ELECTRICITY CONSUMPTION COMPARISON OF MECHANICAL AND ELECTRONIC THERMOSTATS

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Abstract- Energy requirement is one of the most fundamental problems all the world. Today, the need for energy is increasing day by day. To meet this need, many projects are being developed around the world and efforts are being made to increase production capacity according to the need through various methods. In addition, efforts are being made to make the systems consume less energy by considering energy efficiency in existing systems. One of the common areas of use of energy is the cooling sector. Making these products, which are used in many places in our daily lives, both domestic and industrial, energy efficient is critical for energy saving. This study was conducted to reveal the effect of thermostat selection on electricity consumption using commercial refrigerator cabinets.

Keywords: Thermostat Selection, Cooling, Mechanic Thermostat, Electronic Thermostat.

1. INTRODUCTION

Today, due to the increasing need for electricity and increasing electricity costs, not only generating electricity but also using it more efficiently is gaining importance. In a report published in 2019, total electricity consumption of the whole world reached 22848 TWh and this represents to 1.7% increment from previous year. Moreover, one year later, in 2019, total electricity consumption of OECD was 9672 TWh. This is 1.1% lower than the total consumption reported in 2018. On the other hand, electricity consumption of the other countries was 13176 TWh, which represents 3.8% increment from 2018 [1]. In parallel with this need, electricity production is increasing day by day. According to the "Global Electricity Review 2023" report of Ember, in 2022 the global electricity generation was 28K TWh [2].

As the importance of the electricity and the cost of generating it is getting increased, the energy efficiency is being more and more important problem. New devices are designed to use less energy and energy harvesting with new materials and smart technologies [3-6]. As the demand and cost of electricity keep increasing, consumers are looking for new methods to reduce their electricity bills [7-9].

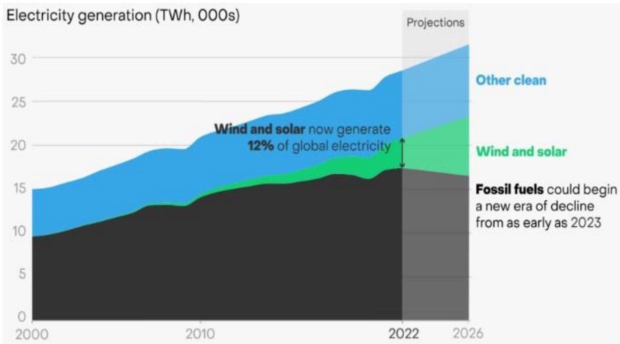

Figure 1. Electricity generation and future projection [2]

In this paper, the electricity consumption of the commercial refrigerator cabinets is investigated. The electricity consumption of these devices using electronic thermostat and mechanical thermostat are compared in real time. The driven voltage, current and power values are measured and recorded together with other parameters as cabinet inner temperatures, room temperatures, room humidity etc.

This paper is organized as follows. In section 2, general information about commercial refrigerator cabinets and cooling system is given. In section 3, measurement setup and measurement conditions is supplied. In section 4, measurement results are given and conclusions are obtained in the final section.

2. COMMERCIAL REFRIGERATOR CABINETS

"According to Energy.gov, commercial refrigerators can use up to 17,000 kilowatt-hours of electricity, while commercial freezers can use up to 38,000 kilowatt-hours of electricity. To put those values into perspective, a typical U.S. house uses on average 10,399 kilowatt-hours per year." [10] This represents the situation only for USA but commercial refrigerators are commonly used all over the world. Some typical devices can be seen in [11]. They consume very big level of electricity and hence reduction of such electricity give a serious amount of cost for owners of them.

Figure 2. Typical commercial refrigerator cabinets [11]

There are many academical works on the performance of commercial refrigerators [12-16]. In this work our focus is on the effect of thermostat selection for electricity consumption.

2.1. Cooling Cycle

In vapor compression mechanical cooling system; The refrigerant, which is compressed to high pressure in the compressor, is sent to the condenser as superheated vapor. Here, the refrigerant, which condenses by giving heat to the environment, is throttled to low pressure in the throttle valve and enters the evaporator in wet-vapour state. The refrigerant, which has a temperature below the ambient temperature surrounding the evaporator, cools the environment by absorbing the heat of the environment and is absorbed by the compressor as saturated vapor at the evaporator outlet (Figure 3) [11]. Thus, the cycle is repeated continuously. The succession of the refrigerant in these processes is called the refrigeration cycle.

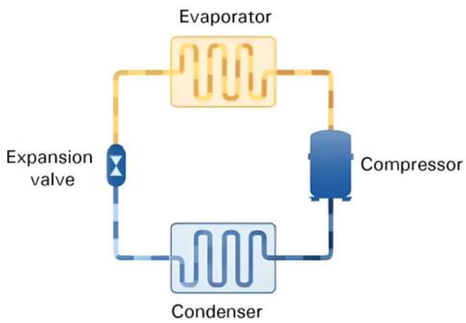

Figure 3. Basic cooling cycle elements [11]

In vapor compression refrigeration cycles, the compressor, which is the component that most affects the performance and safety of the refrigeration system, absorbs the fluid vapor in the evaporator, ensures the evaporation of the liquid fluid entering the evaporator, and also ensures that the boiling point of the fluid does not increase by reducing the pressure in the evaporator below atmospheric pressure. The condenser allows the superheated gas to condense and become liquid by changing phase by releasing its current heat to the environment. The heat loaded in the refrigerant in the evaporator is given out in the condenser and turned into a liquid state that can absorb heat again.

Evaporator is the system element in which the refrigerant boils and evaporates and thus takes the heat from the environment to be cooled. This system element refers to a pipe winding or a surface designed to absorb heat. When the inner temperature of the refrigerator reaches the desired (pre-determined) value, the refrigeration cycle is stopped and the temperature reduces another predetermined value, the refrigeration cycle starts again. Solely, the inner temperature of the refrigerator is tried to be kept constant level. This is controlled by a thermostat. As one of the core components of the cooling system, the thermostat is very critical for performance of the system.

2.2. Mechanical and Electronic Thermostats

The thermostats are used to control temperature by working as a switch. Thermostats can be mechanical or electronic but nowadays electronic thermostats ra preferred frequently. In general, older devices use mechanical thermostats whereas new devices use electronic thermostats. Mechanical thermostats use mechanical parts to sense temperature changings whereases electronic thermostats use electronic sensors for thermal measurements. First of all, thermostat (or thermal switch) is tuned a predefined temperature (or interval of temperature), then when this temperature is achieved, its switch changes its position. In this way many devices like cooling systems, refrigerators, air conditioners etc. can be controlled with respect to the thermal effects [17].

In general, mechanical thermostats are cheaper, than the electronic ones. Hence, manufacturer may prefer to use mechanical thermostats to decrease the cost of the devices. On the other hand, the response time of the mechanical thermostat is slower than the electronic counterpart and they can't react to thermal changes as electronic ones react. The mechanical thermostat advantage is that it is more stable in power swings and this may be a important reasoning to use them [18].

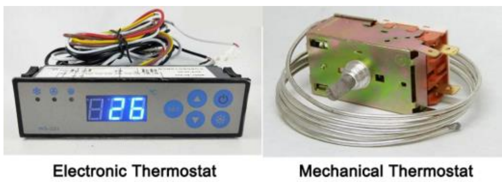

Figure 4. Electronic and mechanic thermostats [19]

3. MEASUREMENT SETUP

For the electricity consumption measurements of commercial refrigerator cabinets while using electronic and mechanical thermostat, standardized test procedure is applied. Cabinet is loaded with soft drink boxes as shown in Figure 5.

This cabinet is first installed with electronic thermostat and then measurements done. Then, same cabinet with same sensors, loads etc. is installed with mechanical thermostat and measurements are repeated. Instead of thermostats, all the remaining parts are same, and other conditions like room temperature, room humidity is measured and tried to be as identical as possible. Cabinet inner temperatures (temperatures of each shelf and all drink boxes separately, total of 30 boxes) are measured during 24 hours as 1 measurement/minute. Energy values are measured using an energy analyzer. Connection points of the cabinet during the measurements are shown in Figure 6.

Figure 5. Installed version of double door commercial beverage cooler

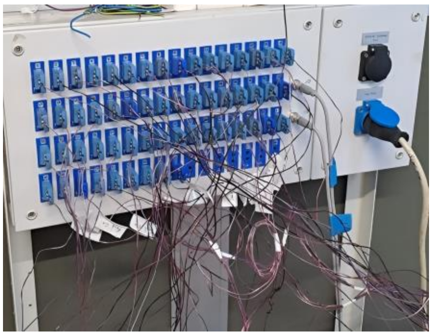

Figure 6. Connection points for measurements

4. MEASUREMENT RESULTS

In the following figures measured temperature and electricity consumption plots are given. The measurements hold for 24 hours (1 measurement/minute) but for the visibility of the figures, only 12 hours and 3 hours portions are included here. In Figure 7, the electricity measurements from energy analyzer for both cases (mechanical and electronic thermostat cases) are given for 12 hours only.

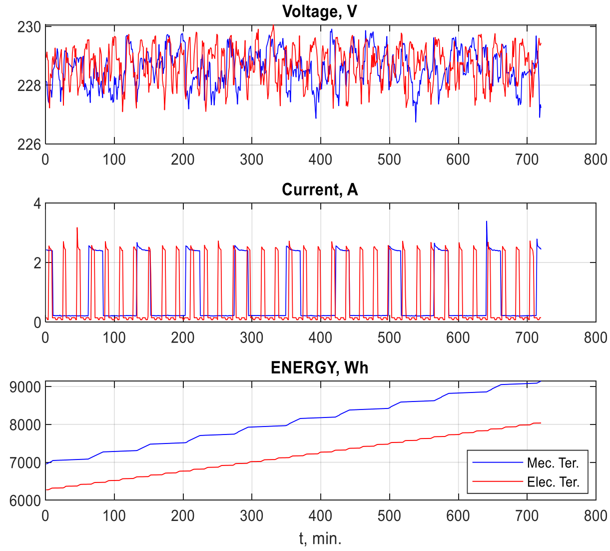

Figure 7. Electricity measurements for both Mechanical and Electronic thermostat cases (for 12 hours)

As it can be seen from Figure 7, the consumption is higher for mechanical thermostat. It is raised from the late response of the mechanical thermostat to the temperature changes. This can be seen from Figure 8 exactly. In Figure 8, the inner temperature measurements of the cabinet for both cases are given. The measurements are taken from the top, middle and bottom levels of the cabinet. It is clear, electronic thermostat can be tuned more sensitively and hence it responds to the temperature changes immediately. Therefore, cooling operation with electronic thermostat takes less time but the number of cooling cycle increases. On the other hand, with mechanical thermostat, total number of cooling cycle reduces but each cycle takes more time. The result of such an operation on the electricity consumption is seen clearly in Figure 7. For more clear and detailed graphics, same figure is given for 180 minutes only in Figure 9.

In measurements, it is observed that the commercial beverage cabinets using electronic thermostats runs for 5 minutes and stays in thermostat (or stand-by) mode for 15 minutes, completing a cooling cycle in just 20 minutes. On the other hand, the cabinet using a mechanical thermostat completes its cycle almost in 72 minutes and inside this 72 minute it runs almost 22 minutes. Hence it effects electricity consumption as well as inner temperatures of the cabinet.

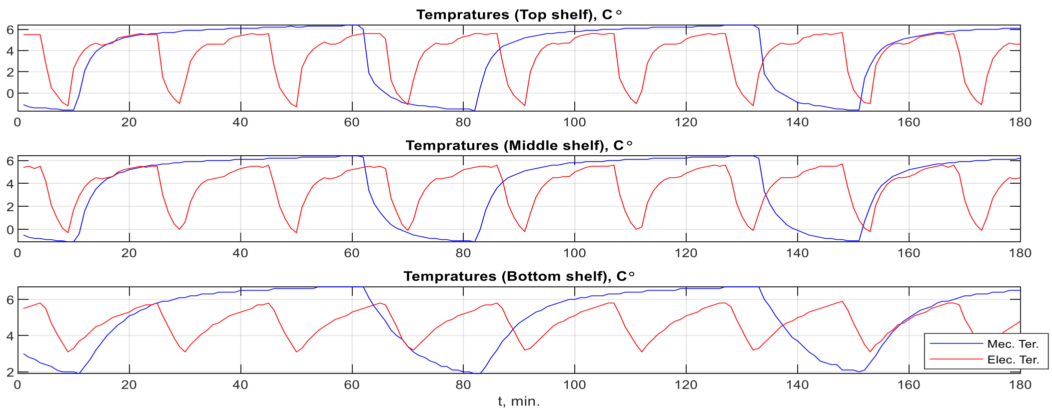

Figure 8. Cabinet inner temperature measurements for both cases - Measurements are done at the bottom, middle and top locations of the cabinet

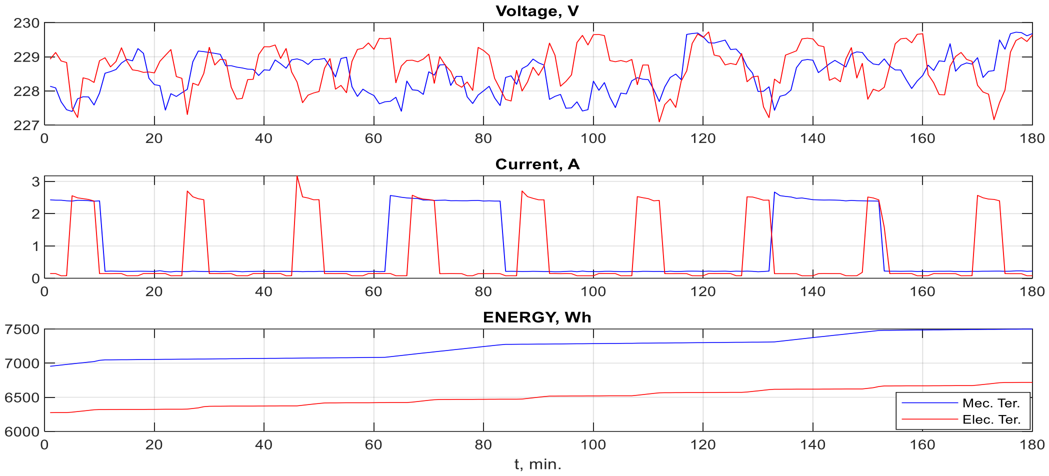

Figure 9. Electricity measurements for both mechanical and electronic thermostat cases (for 180 minutes)

5. CONCLUSIONS

In this work, the effect of thermostat selection on the electricity consumption of the commercial refrigerator cabinets are investigated. Same cabinet is tested while using electronic thermostat and mechanical thermostat separately by satisfying all other parameters remain same. The measurements shows that commercial refrigerator (beverage) cabinets using electronic thermostats consume less energy with shorter cycle times. It runs for 5 minutes and stays in thermostat mode for 15 minutes, completing a cycle in just 20 minutes. While it consumes only 44 Wh of energy during this period, the cabinet using a mechanical thermostat consumes 192 Wh of energy in its 72-minutes cycle. This huge difference clearly shows that the electronic thermostat works more efficiently in terms of both electricity consumption and cooling performance. Additionally, the cabinet using an electronic thermostat completes its cooling cycle 72 times in a day (24 hours). This means that the total daily energy consumption is 3168 Wh, while the cabinet using a mechanical thermostat cooling cycles only 19 times and consumes a total of 3648 Wh of energy per day. The ability of the electronic thermostat to cycle more frequently and perform the same function with less energy provides a great advantage in terms of energy efficiency.

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