

Research Article

Development of IoT-based Air Conditioning Trainer Assisted with Four-Way Reverse Valve**Vaibhav Jain^{1,*}, Neelam Sharma², Krishna Anurag Tripathy³, Akshat Dixit⁴, Naman Srivastava⁵, Vibhor Suryavanshi⁶, Prabhat Choraria⁷ and Saurabh Dabral⁸**¹Associate Professor, Department of Mechanical Engineering, Maharaja Agrasen Institute of Technology (MAIT), Delhi, 110086, India.²Professor, Department of ECE, Maharaja Agrasen Institute of Technology (MAIT), Delhi, 110086, India.²⁻⁸Student, Department of Mechanical and Automation Engineering, Maharaja Agrasen Institute of Technology (MAIT), Delhi, 110086, India.*Corresponding Author: Vaibhav Jain. Email: vaibhavjain@mait.ac.in

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Abstract: With the cost of gas increasing day by day and the switch to renewable sources of electricity becoming more viable, there is a need for a system that works as an air conditioner year-round. Therefore, the solution to this problem is to design a single unit that works as an air conditioner in the summer and as a heater in the winter, while being energy efficient. Electric resistance heaters are expensive and consume more power, increasing operational costs. To overcome this problem, a single unit is designed that performs for around a year and is cost-effective. This device is suitable for its functionality in the climate of India. The major component that helps in gathering the data for predictive maintenance and remote control through smartphones is the Internet of Things (IoT). By establishing a connection between the air conditioner and the internet and web servers, it is possible to remotely control and monitor the device, as well as automate certain functions.

Keywords: IoT, Vapor Compression Refrigeration Cycle, Power Consumption, Round-the-Year AC, HVAC.

1. Introduction

Refrigeration and air conditioning systems have dramatically improved over the years in performance, reliability, and energy efficiency [1]. That's mostly been due to technological advancements of each individual component, making them digital and being able to connect as well as communicate with other components in the system [2]. In the beginning, purely mechanical components such as valves and pressure gauges, which all operate individually, were available. They are manually controlled, and they rely on a human operator. Then, components started to become electronic, and expansion valves went from simple fixed orifice devices to thermostatic mechanical valves. Now, the use of stepper motors and electronic controls offers very precise control [3-5]. At one point, pressure and temperature sensors were visual only with mechanical moving parts, and now the increased use of electronics provides better accuracy in measurements and relays this information to a controller. Even liquid level sensors can now not only tell us the level of refrigerant in a system, but they also use microwaves to detect refrigerant states. The best example of such is the Heat pump. The heat pump has evolved to become a mature technology over the past two decades. It is not, however, utilized as broadly as it could or ought to be. Since just a handful of the major refrigeration system makers offer large-scale heat pumps, initial pricing, system design, and integration continue to be difficult issues. To reduce net energy consumption and, consequently, greenhouse gas emissions, energy must be used efficiently in processes like district cooling and heating, drying, and cogeneration. Energy



conservation will become a top issue in many industrial operations as a result of the ultimate implementation of a carbon/energy tax on a global scale. The interest in HP as a method of energy recovery seems to have been revived with the rising expense of fuel and global warming at the forefront of public attention. One of the most workable solutions to the greenhouse effect is provided by heat pumps[6-8]. It is the only procedure that is currently known to recycle environmental waste heat back into a heat production process, providing environmentally friendly and energy-efficient heating and cooling in a variety of applications, including residential and commercial buildings and process industries. Heat pumps have the ability to significantly cut greenhouse gases, particularly CO₂ emissions, when used for space heating and heat generation, according to real-world studies, with a new phase of internet connectivity and big data through IOT or Internet of Things. This allows everything to be connected, monitored, optimized, and even operated using artificial intelligence and machine learning [9-10].

This is the future of the HVAC (Heating, ventilation, and air conditioning) industry. The question might arise as to why there is a need to connect systems and components. The sole reason is the ease of use that comes with it, which is an added benefit of IOT. With the help of mobile phones, devices can be controlled from anywhere in the world [11]. It gives full control over the unit, such that it can set the desired room temperature, change modes, change the speed of the fan, and set a schedule to turn on or off the unit. Sensors are attached to almost all the components within the unit [12]. This makes the user aware of the energy consumption as well as reminds them to change filters when the filter gets dirty. When a fault occurs in the AC, it takes a long time to get it serviced. The ideal workflow looks like this: first reporting the problem, on which a technician inspects the problem and sends a request for spare parts. On the arrival of that specific spare part, an engineer comes and installs the new part, and then the whole process is over. With the help of IOT, the problem is already known to the user as well as saved on the cloud database of the company. With just one click on the phone, the engineer can come with that specific spare part and can fix the unit, resulting in less time spent, reducing travelling emissions as well as money expenditure[13-15].

2. Literature Review

Removing heat from a container or a substance in order to lower the temperature is known as refrigeration. The second law of thermodynamics governs how refrigerators function. Unwanted heat is transferred from one area to another throughout the refrigeration process. The typical residential refrigerator in homes operates on the evaporation principle. In a heat cycle, a refrigerant is a chemical that moves heat from one place to another. A refrigerant passes through the food items in a refrigerator, absorbing heat from them and transferring it to an area with a lower temperature. This process was witnessed in the Greek and Roman periods to cool their food with ice transported from the mountains. Preservation of the food is the main idea that leads to the development of the refrigeration process. Refrigeration inhibits the growth of microorganisms like bacteria, yeast, and mold, thus helping in the destruction of food items. While a heat pump warms the external fluid passing through the condenser, a refrigeration system cools the external fluid passing through the evaporator. The method of cooling or heating operation is the primary distinction between a heat pump and a refrigerator. The refrigerator system consists of four parts. Evaporator, Compressor, Condenser, and Expansion Valve are all of them.

2.1 Evaporator

The refrigerator's main component keeps the appliance and its contents cool at all times. High thermal conductivity tubes are a feature of the system that aid in collecting heat released by the fan or coil.

2.2 Compressor

The low-pressure, low-temperature vapour is compressed by the compressor into a high-temperature, high-pressure vapour. A cylinder is used to compress the refrigerant after it leaves the evaporator in order to create a high-temperature, high-pressure gas.

2.3 Condenser

The refrigerator's rear contains a group of tubes with external fins. This element aids in turning the gaseous refrigerant into a liquid.

2.4 Expansion valve

Assists in managing the refrigerant flow into the cooling coil or evaporator. Flow control valves are another name for expansion valves. It is a delicate, compact instrument that helps detect changes in the refrigerant's temperature.

3. Selection of Material

Refrigerant- R32

R32 is a hydrofluorocarbon (HFC) refrigerant having the chemical formula CH₂F₂ (difluoromethane). R32 is an environmentally friendly alternative refrigerant with a low GWP and no ozone depletion potential (ODP). It has superior thermodynamic qualities, energy economy, and safety features, making it a popular choice for air conditioning and heat pump applications. As a result, in Table 1, we have used R32 as the refrigerant in the project model.

Table 1: Properties of R32 (refrigerant)

Property	Value	Units
Chemical Formula	CH ₂ F ₂	N/mm ²
Molecular Weight	52.02	g/mol
Boiling Point	-51.7/-61.1	°C/°F
Critical Temperature	78.1/172.6	°C/°F
Critical Pressure	5.8/841.4	MPa/psi
Global Warming Potential(GWP)	675 (over a hundred-year-old period)	N/A
Ozone Depletion Potential(ODP)	0 (it does not deplete the ozone layer)	N/A

4. Working

4.1 Cooling mode

The cooling mode of a vapour compression refrigeration system (VCRS) involves

removing heat from the indoor environment. The components used in the system include a compressor, condenser, expansion valve, and evaporator. The compressor raises the temperature and pressure of the refrigerant vapour, which is subsequently condensed and converted into a high-pressure liquid in the condenser, releasing heat. The pressure and temperature of the refrigerant fall as it goes through the expansion valve before entering the evaporator. The refrigerant takes heat from the indoor air in the evaporator, evaporating it and generating cool air. The VCRS can cool the room by removing heat from the indoor environment using this continuous cycle. Figure 1 shows the Cooling mode circuit.

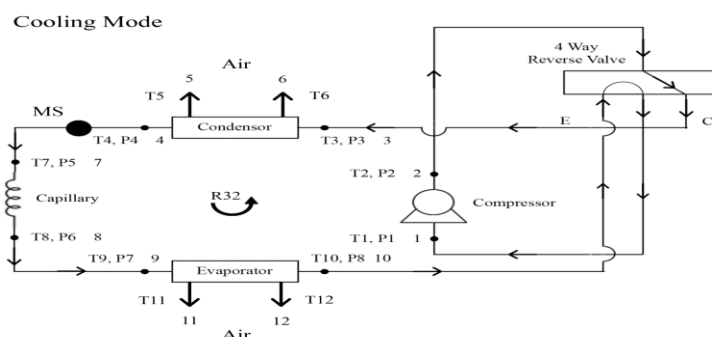


Figure 1: Cooling mode circuit

4.2 Heating mode

Heat pumps work by using a refrigeration cycle to transfer heat from one place to another. In heating mode, the refrigeration cycle is reversed, and heat is extracted from the outdoor air (even in cold temperatures) and transferred indoors to warm the space. A heat pump is the primary heating mechanism in air conditioning systems with heating capacity. By reversing the refrigeration cycle, the heat pump absorbs heat from the outside air and transfers it indoors to warm the room. In severely cold weather, electric resistance heaters can be utilised to provide additional warmth. These heaters boost the heat pump's heating capacity to ensure optimal comfort. Air conditioning systems can perform both cooling and heating functions due to the heat pump and auxiliary heaters, giving them versatile options for maintaining desired indoor temperatures all year. Figure 2 shows the Heating mode circuit.

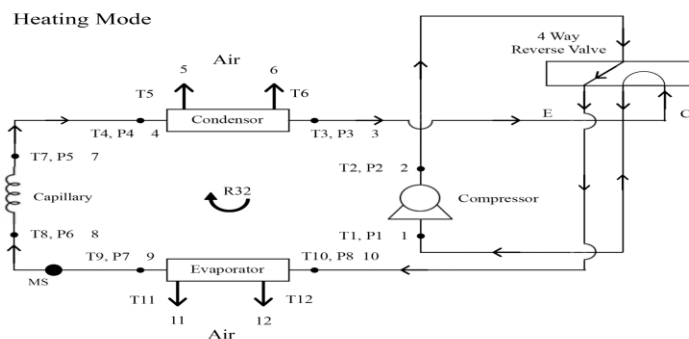


Figure 2: Heating mode circuit.

4.3 Combined system

By using the valve to reverse the refrigerant flow, the combined heating and cooling mode is accomplished. This valve eliminates the need for extra components by allowing the system to transition between cooling and heating modes. The 4-way reversing valve controls the flow of refrigerant in cooling mode to remove heat from the inside air and release it outdoors, resulting in cooling. The valve changes the refrigerant's flow direction while it is in the heating

mode. Even in frigid weather, it draws heat from the outer air rather than the air within. Then, to warm the area within, this heat is transmitted. The air conditioning system's capacity to flip between heating and cooling modes, enabling year-round comfort and temperature control, depends heavily on the 4-way reversing valve. Figure 3 shows the Four-way reverse valve.

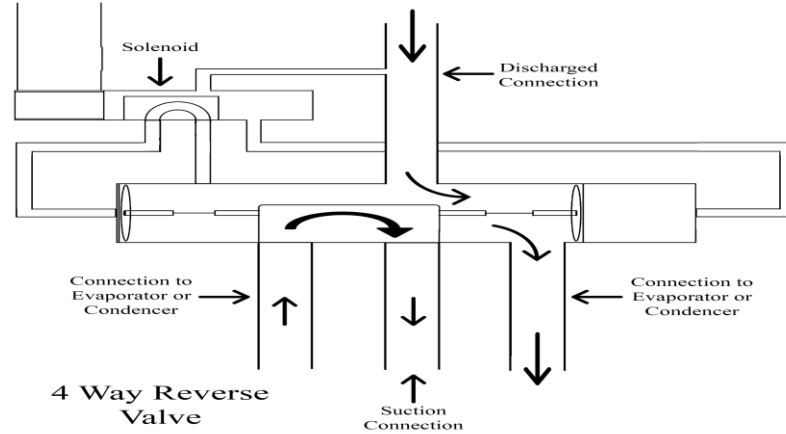


Figure 3: Four-way reverse valve.

4.4 Implementation of IOT Techniques

The Internet of Things (IoT) holds enormous promise in a variety of fields, including smart cities, industries, and healthcare. A smartphone app or web-based interface for remote control and data processing would be developed as software components. Through the app or interface, users may remotely manage the air conditioner, set schedules, and check energy usage. Because of their open-source nature and interoperability with programming languages such as C and Python, Raspberry Pi and Arduino are widely used for IoT applications. This research focuses on combining Raspberry Pi and Arduino to monitor and adjust the temperature and humidity of a server room. The temperature and humidity are measured by the DHT22 sensor, and the data is processed by the Raspberry Pi. If the values exceed defined thresholds, notifications are sent, and the actuator (Arduino) adjusts the air conditioner accordingly. The system also allows remote access through an Android application and data storage in a database for analysis. Overall, this design enables efficient monitoring and control of environmental conditions in the server room using IoT technology.

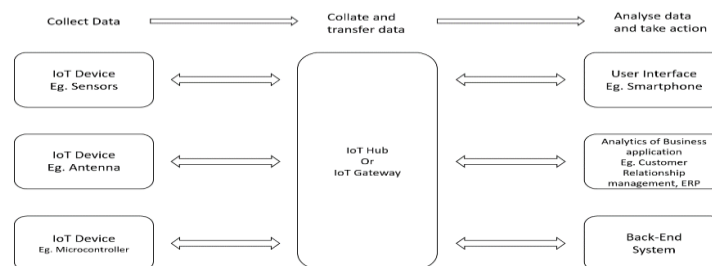


Figure 4: IoT Flow chart

5. Result & Discussion

The results have been categorized into two categories

VCRS

With the help of EES software, the thermodynamic analysis of the cooling system was

performed, and various terms were found. Study of the 4-way reverse valve and the literature survey of cooling and heating devices used in VCRS.

Performance losses due to 4-way reverse valves are known to decrease the efficiency of heat pumps. There are three losses associated with the reversing valve.

- Heat transfer between the hot and cold gases flowing through the valve.
- Pressure drops across the valve caused by bends and sharp entries and exits.
- Refrigerant leakage from the high-pressure side to the low-pressure side of the valve.

Installation is possible for the 4-Way reversing valve only in the horizontal position; the orientation should be in the range from 0° to 180° . In the vertical position, the valves can be installed in any orientation as long as the coil stem position is up. Before installing, thoroughly clean the inner part of the pipes to prevent dust or dirt particles from entering the valve. Use an 80 to 100 mesh strainer at the valve inlet, if dust or dirt particles inside the pipes may flow into the valve.

6. Conclusion

In addition to being more costly initially, electric resistance heaters increase running expenses due to their high power consumption. A cost-effective, single-unit solution is developed to address this issue all year round. In terms of its intended use, this device is well-suited to the Indian environment. The Internet of Things (IoT) is a crucial component that aids in data collection for predictive maintenance and remote control via smartphones. It is feasible to automate specific operations, get remote control and monitoring capabilities, and connect the air conditioner to the internet and web servers.

Nomenclature

AC	Air Conditioner
IOT	Internet of Things
HP	Heat Pump
CO ₂	Carbon Dioxide
HVAC	Heating Ventilation and Air Conditioning
VCRS	Vapour Compression Refrigeration System
VARs	Vapour Absorption Refrigeration System
COP	Coefficient of Performance
EES	Engineering Equation Solver
AQI	Air Quality Index
PM	Particulate Matter

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