DAYANANDA SAGAR COLLEGE OF ENGINEERING

Accredited by National Assessment & Accreditation Council (NAAC) with 'A' Grade

(AICTE Approved, an Autonomous Institute Affiliated to VTU, Belagavi)

Shavige Malleshwara Hills, Kumaraswamy Layout, Bengaluru-560111

DEPARTMENT OF MECHANICAL ENGINEERING

(Accredited by NBA)

A Project Report on

"MODELLING AND SIMULATION OF YEAR AROUND HVAC SYSTEM USING GEOTHERMAL ENERGY."

Submitted in partial fulfilment for the award of degree of

BACHELOR OF ENGINEERING

in

MECHANICAL ENGINEERING

Submitted by

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2023-24

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Certificate

Certified that the project report entitled "**MODELLING AND SIMULATION OF YEAR AROUND HVAC SYSTEM USING GEOTHEMAL ENERGY"** is a bonafide work carried out by **Mr. Harish P**, bearing USN**: 1DS19ME056**, **Mr. L Harsha** bearing USN**: 1DS19ME078**, **Mr. Lakshminarayan A H** bearing USN**: 1DS19ME079**, **Mr. Manjunath Badagar** bearing USN: **1DS19ME086** under the guidance of **Dr. M.R Kamesh**, Professor, Department of Mechanical, Dayananda Sagar College of Engineering, Bengaluru, in partial fulfilment for the award of Bachelor of Engineering in Mechanical Engineering under Visvesvaraya Technological University, Belagavi.

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DECLARATION

We the below mentioned students hereby declare that the entire work embodied in the project report entitled '**MODELLING AND SIMULATION OF YEAR AROUND HVAC SYSTEM USING GEOTHEMAL ENERGY**' has been independently carried out by us under the guidance of **Dr. M.R.Kamesh,** Professor, Department of Mechanical Engineering, Dayananda Sagar College of Engineering, Bengaluru, in partial fulfilment of the requirements for the award of Bachelor Degree in Mechanical Engineering of Visvesvaraya Technological University, Belagavi.

I further declare that I have not submitted this report either in part or in full to any other university for the award of any degree.

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ABSTRACT

As global living standards, economic growth, and population continue to rise, the demand for cooling and air conditioning is set to surge in the next 30 years. There is a pressing need to address the associated energy consumption and environmental impact. Refrigeration and air conditioning systems using heat pumps currently account for a significant portion of global energy usage. Without improvements in energy efficiency or the introduction of new technologies, electricity usage could triple by 2050. In this project, we aim to explore the potential of ground-source heat pumps (GSHPs) to optimise heat pump performance by increasing the COP of the systems, reducing compressor work, and achieving substantial energy savings. GSHPs utilise the thermal properties of the ground to enhance the efficiency of heat transfer processes.

Our project aims to simulate ground-source heat pumps, which enhance the effectiveness of heat pumps and significantly increase energy savings. By optimising the operation of these heat pumps in CycleTempo Software, we can help address the growing demand for cooling while minimising energy consumption. Through detailed simulations and analysis, we investigate various operational parameters, including the degree of superheating and subcooling, to identify the optimal configurations for GSHP systems. Additionally, we assess the performance of different refrigerants, such as R134a, R142b, ammonia, and benzene, to determine their suitability for achieving energy-efficient operation. Our findings provide valuable insights into the design and operation of GSHPs, paving the way for sustainable cooling solutions and reduced environmental impact.

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Chapter 1: Introduction

With the ongoing global trend of rising living standards, economic growth, and population growth, the demand for cooling and air conditioning is anticipated to skyrocket over the next 30 years. Refrigeration and air conditioning now account for approximately 17% of global energy consumption[l,] totalling approximately 2000 TWh[2]. If the energy efficiencies of these systems are not improved or new technologies are not introduced, electricity usage could triple by 2050[2].

The vast majority of domestic, transportation, and commercial refrigeration, heat pumping, and air conditioning systems use vapour-compression technology,[3] which is a mature technology with low production and maintenance costs as well as safe and dependable operation. Refrigeration, heat pumping, and air conditioning systems have relatively high energy efficiencies (for large-scale appliances, second-law efficiencies can reach.

However, Small-scale appliances typically have low efficiencies, averaging around 20% based on the Carnot cycle, indicating significant room for improvement. The main drawback of vapour compression technology is the harmful environmental impact of the refrigerants currently in use, which contribute 7.8% of global greenhouse gas emissions.

As a result, considerable effort is being devoted to finding alternative refrigerants for everyday air conditioning and refrigeration. Despite the limited availability of environmentally friendly refrigerants, hydrofluorocarbons are expected to be phased out globally within the next 30-40 years [5]. In addition, researchers are exploring alternatives to vapour-compression technology (Figure 1), with the current urgency driving the development of radical technologies such as absorption and adsorption refrigeration. These hold great promise, especially when waste or renewable heat is available.

Refrigeration and air conditioning systems using vapour-compression technology have been the industry standard for many years due to their low production and maintenance costs, as well as their reliable operation. [6] Additionally, the refrigerants traditionally used in these systems, such as hydrofluorocarbons (HFCs) and chlorofluorocarbons (CFCs), have been found to have a detrimental impact on the environment, contributing to global warming and ozone depletion. [7]

Geothermal heat pumps stand out among the many strategies used to raise these systems' coefficients of performance (COP). Integrating geothermal systems with HVAC systems offers a promising response to the growing demand for environmentally responsible cooling and heating techniques. Energy efficiency will be increased, and environmental harm will be reduced, thanks to its integration.

A ground-source heat pump (GSHP), also known as a geothermal heat pump or ground-coupled heat pump, is a heating and cooling system that uses the constant temperature of the ground or a water source as an energy exchange medium. It operates based on the principle that the ground remains relatively stable in temperature throughout the year, regardless of seasonal variations in air temperature.

Ground Temperature: The ground temperature remains relatively stable throughout the year, Temperatures of the earth 10 feet below ground are consistently between 50°F and 60°F.depending on the location and depth. This stability is due to the insulating properties of the Earth's crust. Geothermal heat pumps utilize the ground as a heat source in winter and a heat sink in summer.

- In Winter: The ground temperature is warmer than the outdoor air temperature during winter. Geothermal heat pumps extract heat from the ground through a series of underground pipes, called ground loops, which are buried several feet below the surface. The ground loops transfer heat to the heat pump, which then distributes it to the indoor space for heating.

- In Summer: Conversely, during summer, when the outdoor air temperature is higher than the ground temperature, geothermal heat pumps use the ground as a heat sink. The heat pump extracts heat from the indoor space and transfers it to the ground via the ground loops, where it dissipates into the cooler ground.

While geothermal systems may have higher upfront installation costs compared to conventional systems, their long-term cost-effectiveness is undeniable. Geothermal systems primarily require electricity to operate, which is generally cheaper than the ongoing expenses associated with fuelling combustion-based equipment. The energy savings achieved by geothermal systems can help offset the initial investment, making them economically viable in the long run.

1.1: Types of geothermal heat pumps system:

There are four basic types of ground loop systems. Three of these horizontal, vertical, and pond/lake are closed-loop systems. The fourth type of system is the open-loop option. Several factors such as climate, soil conditions, available land, and local installation costs determine which is best for the site. All of these approaches can be used for residential and commercial building applications.

Closed-Loop Systems:

a) Horizontal Loop System: This type of geothermal heat pump system involves burying pipes horizontally in trenches dug at a depth of several feet. As shown in figure 1.1 the pipes are typically made of high-density polyethylene (HDPE) and contain a heat transfer fluid, usually a mixture of water and antifreeze. The length and spacing of the pipes depend on the heating and cooling load of the building. Horizontal loop systems require sufficient land area to accommodate the trenches.

b) Vertical Loop System: In a vertical loop system, pipes are installed vertically in deep boreholes ranging from 100 to 400 feet in depth. The number of boreholes and the depth depend on factors such as the soil composition, thermal conductivity, and available space. This type of system is suitable for properties with limited land area since it requires less surface area compared to horizontal loop systems as shown in figure 1.1. Pipes used in the vertical loop system are commonly made of high-density polyethylene (HDPE) or a similar material. They are inserted into the boreholes and connected in a closed-loop configuration. Vertical loop systems require less land area compared to horizontal loop systems since the heat exchange occurs vertically. This makes them suitable for properties with limited available land.

c) Pond/Lake Loop System: If there is a pond or lake nearby, a pond or lake loop system can be employed. In this configuration, a coil of pipes is submerged in the body of water. As shown in figure 1.1 the water acts as a heat source or sink, depending on the season. Pond/lake loop systems are commonly used in commercial or large-scale applications where there is a sufficient water source available. Pond/lake loop systems are commonly used in commercial or large-scale applications where there is a nearby pond or lake available. It is important to consider factors such as water quality and the potential impact on aquatic ecosystems when using a pond or lake loop system.

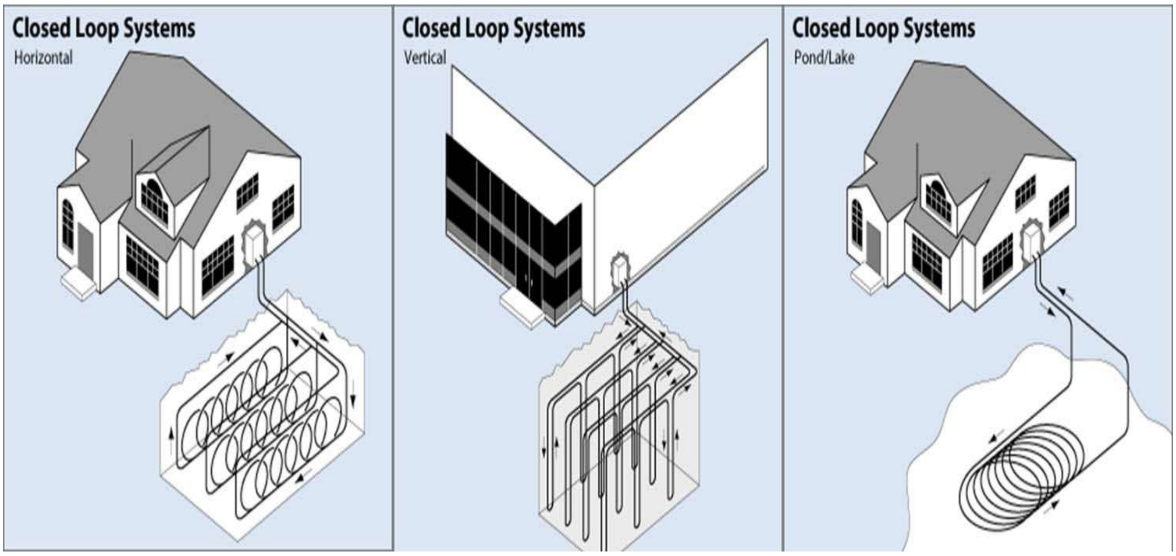

Fig1.1: Types of loop System

Open-Loop Systems:

a) Pump and Dump System: This type of geothermal heat pump system utilizes groundwater as the heat source or sink. Water is extracted from a well, passed through the heat pump to extract or add heat, and then discharged into another well or a body of water. The flow rate of groundwater and the quality of the water source must be carefully considered to ensure optimal system performance and comply with local regulations.

b) Standing Column Well System: In a standing column well system, a single well is used for both extracting and injecting groundwater. Water is pumped to the surface, heat is exchanged with the geothermal heat pump, and the water is then injected back into the same well. This system requires specific geological conditions, such as the presence of an aquifer, and is commonly used in areas where groundwater is abundant and of good quality.

1.2: -Working of ground Source heat pumps (GSHP's):

Winter heating mode:

1. **Circulation:** The above-ground heat pump moves water or another fluid through a series of buried pipes or ground loops as shown in figure 1.2.
2. **Heat absorption:** As the fluid passes through the ground loop, it absorbs heat from the warmer soil, rock, or ground water around it.
3. **Heat exchange and use:** The heated fluid returns to the building where it used for useful purposes, such as space or water heating. The system uses a heat exchanger to transfer heat into the building's existing air handling, distribution, and ventilation system, or with the addition of a desuperheater it can also heat domestic water.
4. **Recirculation:** Once the fluid transfers its heat to the building, it returns at a lower temperature to the ground loop to be heated again. As shown in figure 1.2 this process is repeated, moving heat from one point to another for the user's benefit and comfort.

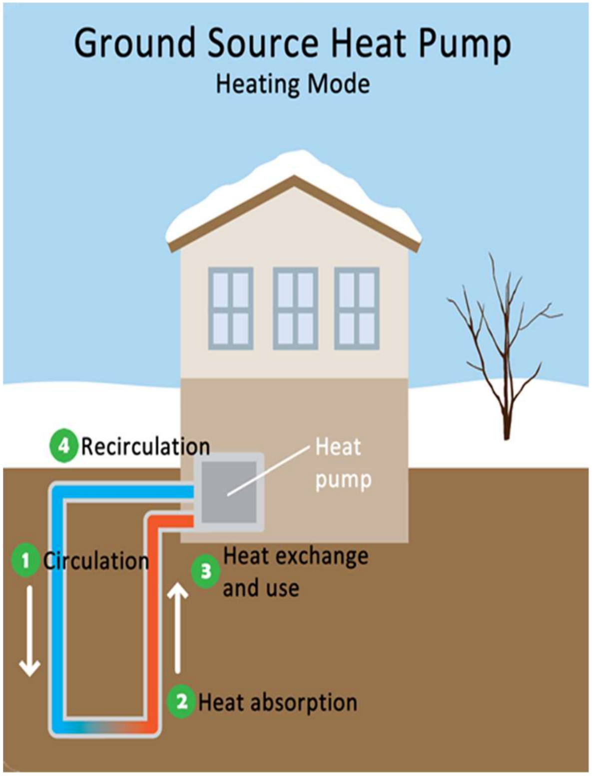

Fig 1.2 GSHP for Heating Mode

<u>Summer cooling mode:</u>

1. **Heat exchange and absorption:** Water or another fluid absorbs heat from the air inside the building through a heat exchanger, which is the way a typical air conditioner work as shown in figure 1.3.
2. **Circulation:** The above-ground heat pump moves the heated fluid through a series of buried pipes or ground loops.
3. **Heat discharge:** As the heated fluid passes through the ground loop, it gives off heat to the relatively colder soil, rock, or ground water around it.
4. **Recirculation:** Once the fluid transfers its heat to the ground, the fluid returns at a lower temperature to the building, where it absorbs heat again. As shown in figure 1.3 This process is repeated, moving heat from one point to another for the user's benefit and comfort.

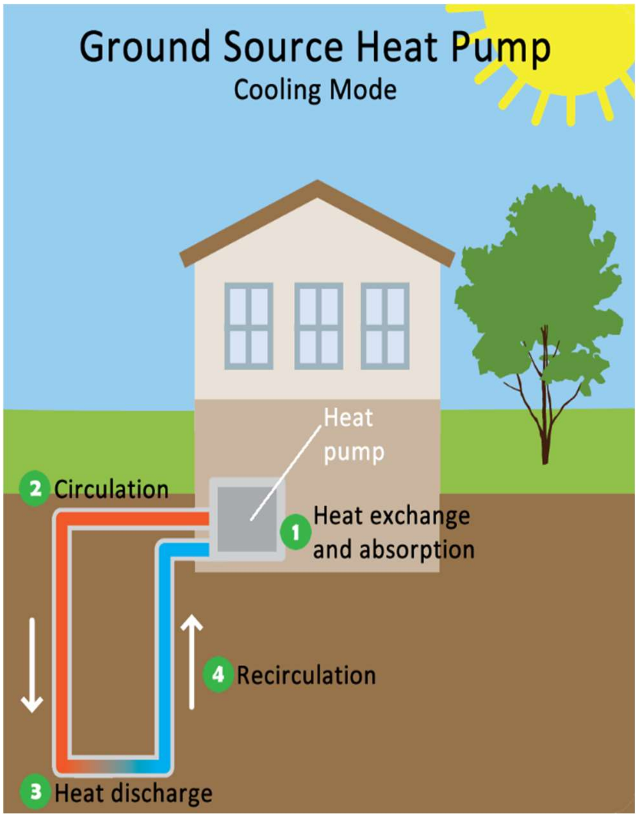

Fig 1.3 : GSHP for Cooling Mode

The above-ground heat pump is relatively inexpensive, with underground installation of ground loops (piping) accounting for most of the system's cost. Heat pumps can support space heating and cooling needs in almost any part of the country, and they can also be used for domestic hot water applications. Increasing the capacity of the piping loops can scale this technology for larger buildings or locations where space heating and cooling, as well as water heating, may be needed for most of the year.

Chapter 2: Literature Survey

This study focuses on using innovative techniques to make use of performance information from contemporary HVAC systems and maintenance management databases. System design must be done correctly, taking into account factors such building type, size, layout, activities, occupants, and climate. Additionally, geothermal heat pumps can be used to increase energy efficiency. The objective is to increase energy efficiency, cut costs, and provide a comfortable interior environment. [8]

Heat pumps are incredibly effective appliances that are utilised in buildings for both heating and cooling needs. When compared to the energy input needed for operation, they produce two to six times as much energy. This study analyses various types and configurations of heat pumps, highlights their diverse practical uses, and discusses the thermodynamic analysis of heating and cooling cycles in heat pumps. Heat pumps provide an excellent way to reduce energy use and emissions while still having effective heating and cooling capabilities. [9][10]

Geothermal energy is a dependable and sustainable renewable energy source utilised for producing power as well as heat. Geothermal heat pumps (GSHPs), which outperform air source heat pumps, have become efficient technology for household and commercial application. To improve system performance, ground heat exchangers and simulation models are being improved. Future research should concentrate on cost reduction, drilling process optimisation, and the creation of hybrid geothermal systems. [11] [12]

For ground source heat pump (GSHP) systems, this study discusses the value of ground investigations. Geological survey, thermal property assessment, and hydraulic conditions research are its three key topics. The need of comprehending the thermo-physical characteristics of the ground is emphasised by the authors for the best GSHP system design. The importance of examining hydrological conditions and the effect of groundwater advection on heat transfer are both emphasised in the paper. Overall, the report highlights the value of specialised research for effective GSHP system sizing and implementation.[13]

The article compares experimentally the performance of vertical and horizontal ground-source heat pump (HGSHP) systems for greenhouse heating in temperate climates. According to the study, both systems produced heating coefficients of performance (COP) for HGSHP that ranged from 3.1 to 3.8 and for VGSHP that ranged from 3.2 to 3.8. Additionally, the change in ground temperature over the course of the heating season was examined at various depths. Additionally, it was discovered that although VGSHP systems had higher installation costs, they were more effective than HGSHP systems.[14]

The study analyses how various climates' ground source heat pump (GSHP) systems are affected by global climate change. Residential building heating and cooling loads vary based on the climate and the thermal properties of the building. The cooling demand increases as a result of global warming while the heating load decreases. Warming has an impact on GSHP system energy consumption, although the extent of the effect varies depending on the climate and architectural style of the building. In some climates, increasing a building's thermal efficiency can help lessen the impact of global warming on energy use.[15]

In this study, the uses of ground source electrical heat pumps (GSEHP) and ground source absorption heat pumps (GSAHP) in cold climates are compared. The problem of ground thermal imbalance in buildings with a high heating demand is the focus of this project. With no appreciable change in soil temperature after ten years of operation, the data show that GSAHP maintains thermal balance more effectively in extremely cold cities. GSAHP can attain a soil temperature that is on average 4-6°C higher than GSEHP in buildings with only heating load. Overall, GSAHP has promise as a remedy for ground thermal imbalance in cold climates, providing better soil temperature and energy efficiency than GSEHP.[16]

In this study, a Ground-Source Heat Pump (GSHP) system in a vacation hotel in Beijing underwent a thorough exergy analysis. The compressor and ground heat exchanger had the biggest exergy losses, according to the research. The study stresses the value of performing such an analysis to find energy-saving opportunities and enhance GSHP system design. Enhancing these components' effectiveness is essential for raising the system's overall performance. [17][18]

In South Korea, ground source heat pumps (GSHP) are becoming more and more common for heating and cooling structures. Between 2004 and 2007, installations of GSHP systems made about 60% of all renewable energy installations. As of August 2008, more than 551 buildings had GSHP systems with a combined capacity of more than 127.1 MW. Vertical closed loop and groundwater heat pump systems were the most prevalent types. By 2030, South Korea wants to use 11% more renewable energy, with a big emphasis on geothermal energy. [19]

Geothermal heat pumps (GHP) have seen tremendous growth internationally, with installations in more than 30 nations. For heating, cooling, and hot water, the technology makes use of the ground's or groundwater's consistent temperature. With an estimated annual energy consumption of 72,000 TJ, the installed capacity is 12,000 MW globally. GHPs have a high coefficient of performance (COP), ranging from 3 to 6. There are two variations of the technology: ground-coupled (closed loop) and groundwater (open loop). [20]

A closed-loop ground-source heat pump (GSHP) project has been started by the Indian Defence Research & Development Organisation (DRDO) for space heating in remote research facilities. The Snow & Avalanche Study Establishment (SASE) near Manali, Himachal Pradesh, started a pilot study. For the purpose of heating and maybe cooling the research facilities, the installation incorporates a ground loop coupled to a water-to-water heat pump. In the following step, the heat pump will be connected to practical heating loads and cooling solutions will be investigated.[21]

This study focuses on the use of heat pumps to heat greenhouses with readily available, abundant resources like air or water. When employing geothermal energy in southern Tunisia, the heat pump model is simulated using the TRNSYS programme, and the results display the coefficient of performance (COP), power consumption, and provided power. Furthermore, the findings imply that CO2 can be a competitively performing working fluid for heat pumps.[22]

This study simulates and validates a hybrid ground source heat pump system that uses both auxiliary heat rejecters and ground loop heat exchangers. The supplemental heat rejecter used in the simulation is a direct contact evaporative cooling tower. An actual system's experimental data is used to validate the simulation. After calibrating the heat pump, cooling tower, and plate frame heat exchanger models, the results demonstrate that the simulation offers an appropriate match to the experimental data.[23]

This paper discusses the implementation and simulation of a ground source heat pump (GSHP) system using low enthalpy geothermal resources for space heating and cooling in industrial and domestic applications. The study considers different temperature scenarios, including ambient conditions, winter conditions, and summer conditions, to evaluate the system's performance and efficiency. The results show that the GSHP system is highly efficient and capable of significant energy savings. The paper concludes that GSHP systems should be widely adopted to reduce household energy consumption and carbon footprints, particularly in regions with moderate diurnal temperature variations. [24]

Ground-source heat pump systems offer energy and maintenance benefits, but detailed analysis and simulation have been limited. This research focuses on using annual and multi-year simulations to design and analyse these systems. Models of vertical ground loop heat exchanges and water-to-water heat pumps have been integrated into Energy Plus, allowing for accurate predictions of system performance. The models accurately reproduce manufacturers' data and predict temperature responses. This approach enables comprehensive analysis and ongoing research to improve computational efficiency and study hybrid systems.[25] [26]

The constant ground temperature at shallow depths serves as a reliable heat source or sink for the heat pump. The paper discusses the complex design considerations, including the behavior of the ground, system configuration, and control options. Weather variation's stochastic nature also impacts optimal system design. Initial validation of the ground heat exchanger (GHX) component model against experimental data is presented. [27]

Cold storage is a crucial technology for preserving produce and preventing spoilage. The proposed design aims to address the budget constraints faced by farmers while maximizing profits. By combining a direct evaporative cooling system with supplemental refrigeration in an air conditioning unit, this compact cold storage solution offers cost-effectiveness and reduced energy consumption.[28] The cooling mode of geothermal heating and cooling systems harnesses the earth's heat sink properties to provide efficient cooling for spaces. By leveraging this innovative technology, energy consumption can be reduced, operating costs can be lowered, and environmental impact can be minimized.[29]

This review explores geothermal heat pumps as an unconventional heating technology, comparing them to conventional heating systems in terms of costs, CO2 emissions, and other factors. Geothermal heat pumps are highly efficient, reduce CO2 emissions, and offer economic advantages.[30] Geothermal heat pumps are more expensive and experience decreased efficiency in colder climates, while air-source heat pumps are less expensive but have reduced efficiency in lower temperatures. A numerical simulation compared the combined use of ground and air heat pumps to using only a geothermal heat pump. The results showed a 13.3% reduction in energy consumption with the combined system.[31]

Researchers conducted a study to improve the thermal conductivity of HDPE pipes commonly used in ground-source applications. They proposed a composite material by incorporating aluminium wires into the HDPE pipes. Using computational analysis, they found that the composite achieved a significant enhancement in thermal conductivity, ranging from 25% to 150% compared to regular HDPE, depending on the number and diameter of the wires. As a result, the outer surface temperature of the composite pipes increased, allowing for a reduction in the required pipe length to handle the same heat flux. Additionally, the presence of wires led to a reduction in thermal resistance with periodic variations along the pipe circumference.[32]

Inferences from Literature Survey-

1. System design considerations: The design of HVAC systems, including geothermal heat pump systems, should take into account various factors such as building type, size, layout, activities, occupants, and climate. Proper system design is essential to achieve energy efficiency, cost savings, and a comfortable interior environment.
2. Effectiveness of heat pumps: Heat pumps are highly effective appliances for both heating and cooling needs in buildings. They can produce two to six times more energy compared to the energy input required for operation. Heat pumps offer a way to reduce energy consumption and emissions while providing effective heating and cooling capabilities.
3. Geothermal heat pump systems: Geothermal heat pumps/Ground Source Heat pumps (GSHPs) are efficient technologies for residential and commercial applications. They outperform air source heat pumps and rely on the consistent temperature of the ground or groundwater. Ground heat exchangers and simulation models play a role in improving the performance of GSHP systems.

4. Performance comparison: Studies compare the performance of different types and configurations of ground-source heat pump (GSHP) systems. Factors such as COP, installation costs, and heating load are evaluated. Vertical and horizontal ground-source systems, as well as different climate conditions, are compared to assess their effectiveness and energy consumption.
5. Global perspective: Geothermal heat pumps have gained international recognition and have been installed in various countries. They offer high coefficients of performance (COP) and contribute to energy savings. Different variations of geothermal heat pump technology, such as ground-coupled and groundwater systems, are utilized for heating, cooling, and hot water purposes.

Chapter 3: Objectives

1. To model VCR system using suitable refrigerants in a simulation software.
2. To model a geothermal system using earth tube heat exchanger.
3. To combine both VCR system and geothermal system in a single cycle.
4. To simulate the modelled combined system for winter heating and summer cooling separately.
5. To compare the COP using different refrigerants.
6. To calculate the capacity of the proposed geothermal based VCR system.
7. To validate using basic mechanical problem.

Chapter 4: Methodology

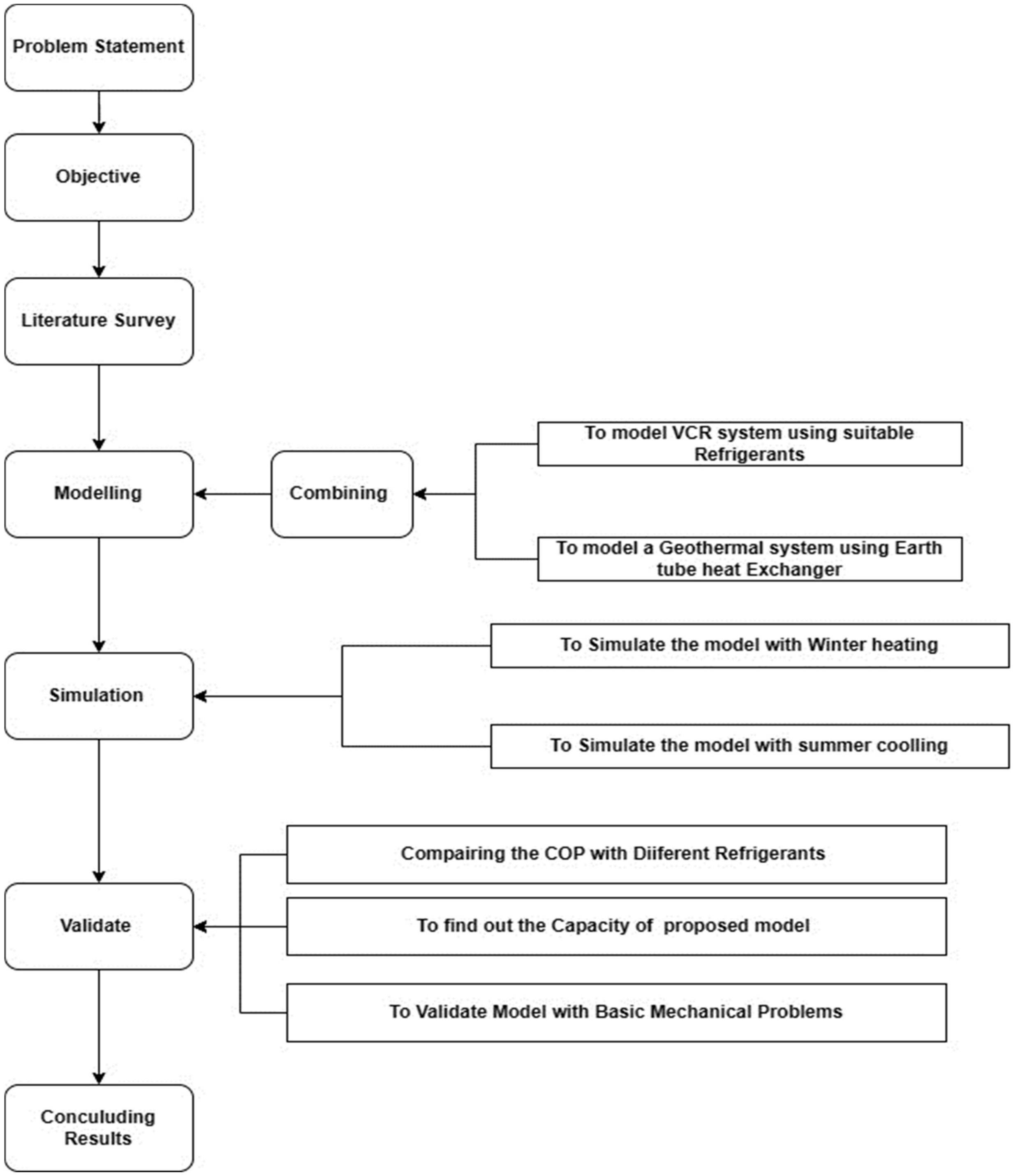

Fig 4.1: Methodology of project

The provided flowchart in Figure 4.1 illustrates the step-by-step approach employed to achieve the stated objective. The methodology commences with identifying the problem statement, which involves conducting heating load calculations for residential buildings during the winter season and cooling load calculations for cold storage facilities. Within the heating load calculation, the focus is on determining the internal heat load and total heat load. On the other hand, the cooling load calculation encompasses the evaluation of transmission load, product load, internal load, and equipment load. The next step is to do a literature review, which involves examining numerous research publications to find any gaps in previous analyses that could be filled in as the basis for the current project.

Cycle Tempo software is then used to model the VCR (Vapour Compression Refrigeration) system and the geothermal system utilising an Earth tube heat exchanger. Then, these two models are combined. The next step is to simulate the model using the parameters listed in the issue statement to get the results for scenarios including summer cooling and winter heating. The proposed model is then tested for capacity, validated against common mechanical issues, and its coefficient of performance (COP) is compared using various refrigerants. Through this validation process, the required results are produced.

Chapter 5: Year Around Heating & Cooling load Calculation

1. Heating load Calculation for Residential building for Human comfort.

1.a) Winter season (Heating mode):

To Calculate the geothermal heating load for a 2,000 square foot house with an R-20 insulated envelope and a tight building envelope with an air infiltration rate of 0.5 air changes per hour (ACH). The house has a basement with an R-10 insulated floor, and a first floor and attic with R-30 insulated ceilings. The windows have a U-value of 0.3, and the doors have a U-value of 0.2. The house has two occupants, and a total internal heat load of 3,000 BTU/hour. The desired indoor temperature is 70°F, and the outdoor design temperature is 10°F.

Solution:

Walls:

Heat loss (BTU/hour) = Area (ft2) x U-value (BTU/hour-ft2-°F) x Temperature difference (°F)

Heat loss (BTU/hour) = 800 x 0.05 x 60

Heat loss (BTU/hour) = 24,000

Roof/Ceiling:

Heat loss (BTU/hour) = Area (ft2) x U-value (BTU/hour-ft2-°F) x Temperature difference (°F)

Heat loss (BTU/hour) = 1,200 x 0.033 x 60

Heat loss (BTU/hour) = 23,760

Floor:

Heat loss (BTU/hour) = Area (ft2) x U-value (BTU/hour-ft2-°F) x Temperature difference (°F)

Heat loss (BTU/hour) = 800 x 0.1 x 60

Heat loss (BTU/hour) = 48,000

Windows:

Heat loss (BTU/hour) = Area (ft2) x U-value (BTU/hour-ft2-°F) x Temperature difference (°F)

Heat loss (BTU/hour) = 200 x 0.3 x 60

Heat loss (BTU/hour) = 4,800

Doors:

Heat loss (BTU/hour) = Area (ft2) x U-value (BTU/hour-ft2-°F) x Temperature difference (°F)

Heat loss (BTU/hour) = 60 x 0.2 x 60

Heat loss (BTU/hour) = 720

Total Envelope:

Total envelope heat loss (BTU/hour) = Sum of heat losses for walls, roof/ceiling, floor, windows, and doors

Total envelope heat loss (BTU/hour) = 24,000 + 23,760 + 48,000 + 4,800 + 720

Total envelope heat loss (BTU/hour) = 101280 BTU/hr.

Component	Area (ft2)	U-value (BTU/hour-ft2-F)	Temperature difference (°F)	Heat loss (BTU/hour)	Heat loss (KW)
Walls	800	0.05	60	24000	7.033
Roof/Ceiling	1200	0.033	60	23760	6.963
Floor	800	0.1	60	48000	14.067
Windows	200	0.3	60	4800	1.406
Doors	60	0.2	60	720	0.2110
Total Envelope				101280	29.682
Air Infiltration				630	0.18
Ventilation				21000	6.1544
Internal Heat Load				3000	0.8792
Total Heating Load				126910	37.1936

Table 5.1: Comparative study for Winter Heating

2.Cooling load calculation for the cold Storage:

Consider a Cold room of dimension 6m*5m*4m. This room should be maintained at $1^0\ c$ @95%RH and the ambient air outside is at 30°c @50%RH.The material of the wall is insulated by material Polyurethane 80mm thick and its conductivity is 0.28 W/m²K and floor temperature is 10°c . The product we are storing is apple which is having Specific heat capacity 3.65kJ/kg k and Respiration heat 1.9kJ/kg per day room stores 4000 kg of apple. In this room 2 People work per day for 4 hours having heat loss rate of 270W/hour and has 3 electric lamps used for 4 hours a day have wattage of 100 W and 3 fans with 14 working hours per day with 200 wattages. Calculate the total cooling of this cold room?

In an HVAC system while calculating Cooling Loads, to calculate Transmission load, Product load, Internal Load and Equipment load.

Transmission loads which will be causing due to heat transmission to the cold room through conduction of walls, cracks, windows and through opening of doors. Products load will be due to the types of products we are storing, its respiration rate and also on its quantity. Internal load depends on the number of people work inside the cold room and number of electric bulbs used there. Equipment load depends on the heat released by the HVAC equipment's.

Solution:

Transmission load

$Q_{transmission} =$ U *A* (Temp out - Temp in) * 24 ÷1000

We need area of all the sides to calculate transmission loads

Side I = 6m x 4m = $24m^2$

Side 2 = 6m x 4m = $24m^2$

Side 3 =5m x 4m = $20m^2$

Side 4 = 5m x 4m = $20m^2$

Roof = 5m x 6m =$30m^2$

Floor = 5m x 6m= $30m^2$

We will calculate the transmission load of all the walls and roof at time because they have same temperature difference and for floor separately because of its different temperature.

Transmission load through Walls and roof:

Q = U x A x (Temp out - Temp in) x 24 ÷ 1000

Q = 0.28W/ m^2K x 118 m^2 x (30°C -1°C) x 24 ÷ 1000

Q 1= 22.99kWh/d

Transmission load through Floor:

Q = U x A x (Temp out - Temp in) x 24 ÷ 1000

Q = 0.28W/m^2K x $30m^2$ x (10°c - 1°c) x 24 ÷ 1000

Q 2 = 1.8kWh/d

Total transmission load $Q_{transmission} =$ Q1 + Q2 = 24.79kWh/d

Product load

Q = m x Cp x (Temp enter - Temp store) / 3600

Q = kWh/d

m = mass of new product per day

Temp enter Temperature of apples entering (°c)

Temp store Temperature inside the cold room (°c)

3600 = Conversion from KJ to kWh

We calculate the heat loss due to temperature difference of the product and heat loss due to respiration of the product separately

Q = m x Cp x (Temp enter - Temp store) / 3600

Q = 4,000kg x 3.65kJ/kg K x (5 -1) / 3600

Q = 16 kWh/d

Q =m x resp ÷ 3600

Q = 20,000kg x 1.9kJ/kg ÷ 3600

Q = 10.5 kWh/d

Total product load due to temperature

difference and respiration of product is

Product exchange 16kWh/d

Respiration 10.5 kWh/d

Total = 26.5 kWh/d

INTERNAL LOAD

Calculating the heat loss due to people work in cold room and also due to using of lamps inside the room.

Heat loss from the people inside cold room

Q = People x Time x Heat ÷ 1000

Q = 2 people x 4 hours x 270 W/hour ÷ 1000

Q = 2.16 kWh/d

Heat from the lamps used inside cold room

Q = Lamps x Time x Wattage ÷ 1000

Q = 3 lamps x 4 hrs/day x 100W ÷ 1000

Q = 1.2 kWh/d

TOTAL INTERNAL LOAD

Q= 3.36 kWh/d

Equipment Load

This load is due to equipment of HVAC system i.e. Heat given off by the fan motors

Q = Fans x Time x Wattage ÷1000

Q = 3 fans x 14 hrs/day x 200w ÷ 100

Q= 8.4 kWh/d

Types of loads	Component	Area (m^2)	U-value (W/m^2K)	Temperature Difference (°F)	Time (Hr)	Heat Loss (KW/day)
Transmission Load Q=U*A*ΔT	**Roof**	30	0.28	29		17.15
	Walls	88	0.28	29		5.85
	Floor	30	0.28	9		1.8
Product load Q=m*Cp*ΔT	**Heat exchange**			4		16
	Respiration					10.5
Internal load Q=n*q*t	**People**				4	2.16
	Lamps				4	1.2
Equipment load Q=n*q*t	**Fans etc.**				14	8.4
Total load						63.6

Table 5.2: Comparative study for Summer Cooling

In Table 5.2, calculations for the cooling loads have been done, which include heat transmitted through the roof, walls, and floor. The heat exchange with the fruits, like the respiration of the fruits, and the people, lamps, fans, etc. involved in the room.

Chapter 6: Simulation Software used

6.1 CYCLE-TEMPO:

Cycle-Tempo is one of the few software packages that allows for exergy analysis. It has been around for more than a decade and has a large user community, including major energy companies, consultancy firms and research and development institutes. It is suited for

- Conventional power plants
- Compression refrigeration and cooling systems
- Unconventional energy systems like:
    - Solar ORC power Plants
    - Tri-generation Systems
    - Absorption-cooling and refrigeration
    - Fuel cells
    - Kalina –cooling and refrigeration systems
    - ScCO2-turbine power plants
    - IGCC power plants

The main feature of Cycle-Tempo is the calculation of all relevant mass and energy flows in the system. It has a particularly robust and efficient computational method, which means that you can depend on it to quickly obtain a reliable solution even in the most demanding situation.

Additional features allow for more detailed analysis and optimization of the system. For example, Cycle-Tempo can perform exergy analysis. Such an analysis provides insight into the exergy flows and losses within subsystems, and allows to quantitavely compare losses of different nature (e.g., fluid dynamic vs heat transfer). It is a fundamental tool when looking for the optimal system configuration and performance.

Furthermore, Cycle-Tempo includes an optimizer that can find the maximum value of a merit parameter (e.g. thermodynamic efficiency or power output).

Cycle-Tempo allows also for real-time integration within existing plant-wide data monitoring systems for performance analysis and trouble shooting.

6.2 Basic Components of Cycle-Tempo:

Heat exchanger as evaporator and condenser

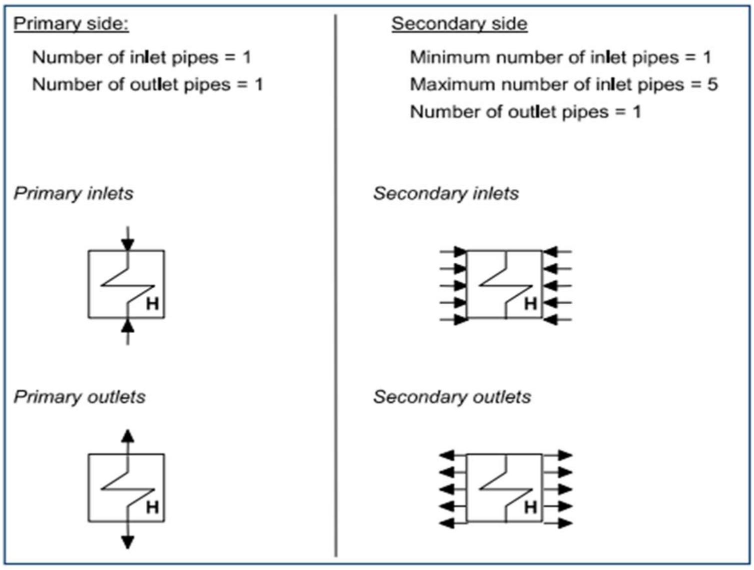

Fig 6.1: Heat Exchanger as Evaporator and Condenser

Input parameters

PINI. POUTI, DELPI, TINI, TOUTI, DELTI are standard

PIN2, POUT2, DELP2, TIN2, TOUT2, DELT2" are standard

The energy equation code (EEQCOD) determines the usage of the energy equation:

- EEQCOD = 1: the energy equation of the apparatus is used to calculate a mass flow. An energy equation, defined by the user (possibly in combination with other apparatuses), can be specified as a production function. If this is not the case, the program will automatically define the production function. In figure 6.1 the value of this function represents the energy release to the environment, i.e. a thermal loss. The energy equation will be added to the system matrix.
- EEQCOD 2: the energy equation of the apparatus is used to calculate an enthalpy in one of the inlets or outlets. The energy equation will not be added to the system matrix

If the EEQCOD is not specified the default value 2 is used.

DELTH = high terminal temperature difference ("E). (Default-UNKNOWN)

DELTL = low terminal temperature difference (°C) (default=UNKNOWN)

RPSM = estimate for the ratio of the primary/secondary mass flow for EEQCOD 2 A negative value indicates a parallel flow heat exchanger and a positive value gives a counter current heat exchanger (default = 1.0). Specification of RPSM is recommended if it is anticipated that the mass flow ratio between primary and secondary medium will differ appreciably from 1. This can prevent fluctuations in the mass flows during the first iteration steps. For EEQCOD-1 only the sign of RPSM is used to determine the flow directions.

DELE = energy flow to the environment (kW) for EEQCOD-2 (default 0.0) DELE> 0 is energy flow to the environment, for example radiation loss. This value, which is used in a local energy balance, can be altered in a user subroutine (APSUB). DELE should differ by at least EPS from -8888.8

6.3 Sink, Source, Expansion value.

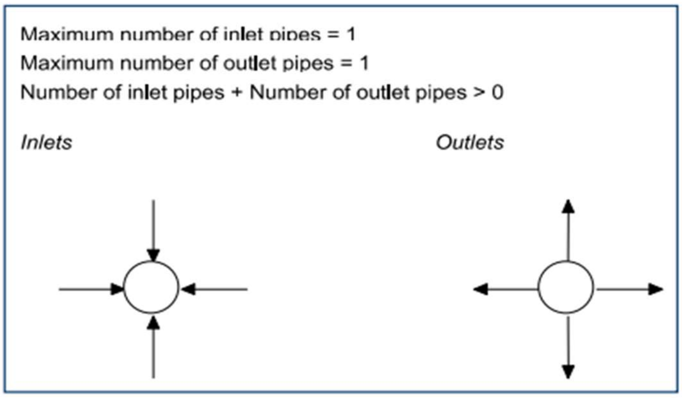

Fig 6.2: Sink, Source and Expansion Value

Input parameters

PIN. POUT, DELP, TIN, TOUT and DELT are standard.

HIN = specific inlet enthalpy (kJ/kg) (default=UNKNOWN)

HOUT = specific outlet enthalpy (kJ/kg) (default-UNKNOWN)

DELH = specific enthalpy difference between inlet and outlet (kJ/kg) (default-UNKNOWN)

The convention is: DELH-HOUT-HIN

Consequently: DELH0 for a specific enthalpy rise. DELH<0 for a specific enthalpy drop. For a pressure reducer DELH-0.0 should be specified.

XIN = vapor fraction at the inlet (-) (default=UNKNOWN), XIN cannot be specified for non-condensing medium types.

XOUT=vapor fraction at the outlet (-) (default=UNKNOWN), XOUT cannot be specified for non-condensing medium types.

DELM = mass flow from or to the system (kg/s) or (-) (default-UNKNOWN)

DELV = volume flow from or to the system (m/s) or (-)

DELVN = volume flow at normal conditions (1.01325 bar, 0 °C) from or to the system (m/s) or (-) (default-UNKNOWN)

DELE = DELE<0 energy from environment to the system. DELE>0 energy from the system to the environment.

DELE 0 energy from the system to the environment. If DELE is specified, ESTMAS should be specified also as shown in figure 6.2.

energy supply or discharge (kW) (default = UNKNOWN) If DELE is specified the value which is used in a local energy equation, can be altered in a user subroutine (APSUB). The value must differ by at least EPS from -8888.8.

ESTMAS = estimate for the mass flow (kg/s) (default-UNKNOWN) ESTMAS must be specified if DELE has been prescribed to obtain a reasonable specific enthalpy change in the first iteration step as shown in figure 6.2.

6.4 Compressor

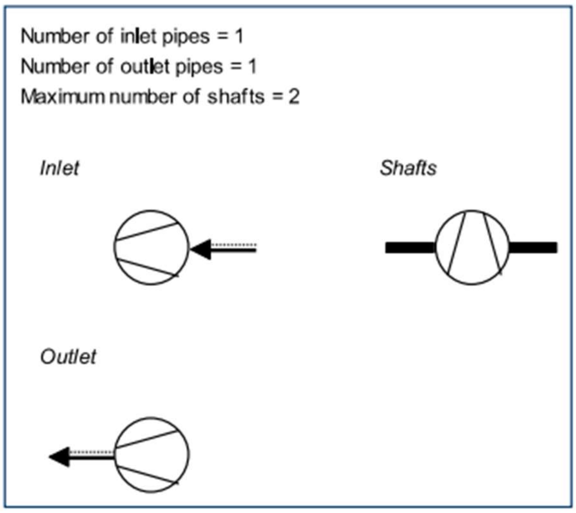

Fig 6.3: Compressor

Input parameters

PIN. POUT, DELP), TOUT, TIN and DELT are standard.

PRATI = pressure ratio (-) (default-UNKNOWN) PRATI is defined as POUT/PIN.

ETHAI = isentropic efficiency (-) (default-UNKNOWN)

ETHAM = mechanical efficiency of drive train (-)

ETHAE = electric efficiency (-)

The basic components of cycle-tempo analysis in mechanical engineering include:

- **Thermodynamic Cycle**: A thermodynamic cycle is a series of processes that convert heat into work or vice versa. The thermodynamic cycle is the heart of the cycle-tempo analysis. It is a theoretical model that describes the energy conversion process in the system.
- **Heat Source**: A heat source is a component that provides the energy input to the system. It could be a combustion chamber, a nuclear reactor, a solar panel, or any other device that provides heat to the system.

- **Heat Sink**: A heat sink is a component that removes the waste heat from the system. It could be a cooling tower, a heat exchanger, or any other device that dissipates the waste heat.
- **Working Fluid**: A working fluid is a substance that undergoes a thermodynamic cycle. It could be a gas, liquid, or a combination of both. The working fluid absorbs the heat from the heat source and releases it to the heat sink.
- **Pump/Compressor/Turbine**: These are the devices that transfer the working fluid from one part of the cycle to another. A pump or a compressor is used to increase the pressure of the fluid, while a turbine is used to generate power from the fluid.
- **Control System**: A control system is used to regulate the operation of the cycle. It could be a simple thermostat or a complex feedback control system.
- **Efficiency Calculation**: The efficiency of the system is a key parameter that is calculated during the cycle-tempo analysis. It represents the ratio of the output work to the input heat.

In summary, the basic components of cycle-tempo analysis in mechanical engineering include the thermodynamic cycle, heat source, heat sink, working fluid, pump/compressor/turbine, control system, and efficiency calculation. Understanding these components is essential for designing and optimizing energy conversion systems.

6.5 Operations in Cycle-Tempo:

The operations of cycle tempo in mechanical engineering involve analyzing and modeling the thermodynamic cycle of an energy conversion system.

The following are the typical operations of cycle tempo:

1. **Define the System**: The first step in cycle tempo is to define the system to be analysed. This includes identifying the working fluid, the heat source, and the heat sink.
2. **Identify the Thermodynamic Cycle**: The next step is to identify the thermodynamic cycle that the system follows. The thermodynamic cycle is a theoretical model that describes the energy conversion process in the system. There

are several different types of thermodynamic cycles, such as the VCR ,Carnot cycle, Rankine cycle, Brayton cycle, and others.

3. **Construct the Cycle Diagram**: A cycle diagram is a graphical representation of the thermodynamic cycle. It shows the various processes that occur in the cycle, such as compression, expansion, heating, and cooling. The cycle diagram helps to visualize the energy conversion process and identify potential areas for optimization.
4. **Calculate the Performance Parameters**: The next step is to calculate the performance parameters of the system, such as the thermal efficiency, the work output, and the heat transfer rates. These parameters provide a quantitative measure of the system's performance and help to identify areas for improvement.
5. **Optimize the System**: Based on the results of the analysis, the system can be optimized to improve its performance. This may involve adjusting the operating conditions, changing the design of the components, or selecting a different working fluid.
6. **Evaluate the Results**: The final step in cycle tempo is to evaluate the results of the analysis and determine the feasibility of the system. This includes assessing the economic viability, environmental impact, and safety considerations.

In summary, the operations of cycle tempo in mechanical engineering involve defining the system, identifying the thermodynamic cycle, constructing the cycle diagram, calculating the performance parameters, optimizing the system, and evaluating the results.

6.6 Application of Cycle Tempo:

Cycle tempo, also known as thermodynamic cycle analysis, is an essential tool used in mechanical engineering to analyse and design energy conversion systems.

Here are some applications of cycle tempo in mechanical engineering:

1. **Internal Combustion Engines**: Cycle tempo is used to analyse the thermodynamic cycle of internal combustion engines. It helps to optimize the design of the engine and increase its efficiency.
2. **Gas Turbines**: Cycle tempo is used to analyze the thermodynamic cycle of gas turbines. It helps to optimize the design of the turbine and increase its efficiency.

3. **Steam Power Plants**: Cycle tempo is used to analyze the thermodynamic cycle of steam power plants. It helps to optimize the design of the power plant and increase its efficiency.
4. **Refrigeration Systems**: Cycle tempo is used to analyze the thermodynamic cycle of refrigeration systems. It helps to optimize the design of the system and increase its efficiency.
5. **Heat Pumps**: Cycle tempo is used to analyze the thermodynamic cycle of heat pumps. It helps to optimize the design of the heat pump and increase its efficiency.

In summary, cycle tempo is an important tool used in mechanical engineering to analyze and design energy conversion systems, such as engines, turbines, power plants, refrigeration systems, and heat pumps. It helps engineers to optimize the design of these systems and increase their efficiency.

Chapter 7: Modelling of HVAC system

Simulation of the basic HVAC system for different conditions

1. Dry after compression
2. Wet after compression
3. Superheat after compression
4. Superheat before compression

1.<u>Wet After Compression</u>

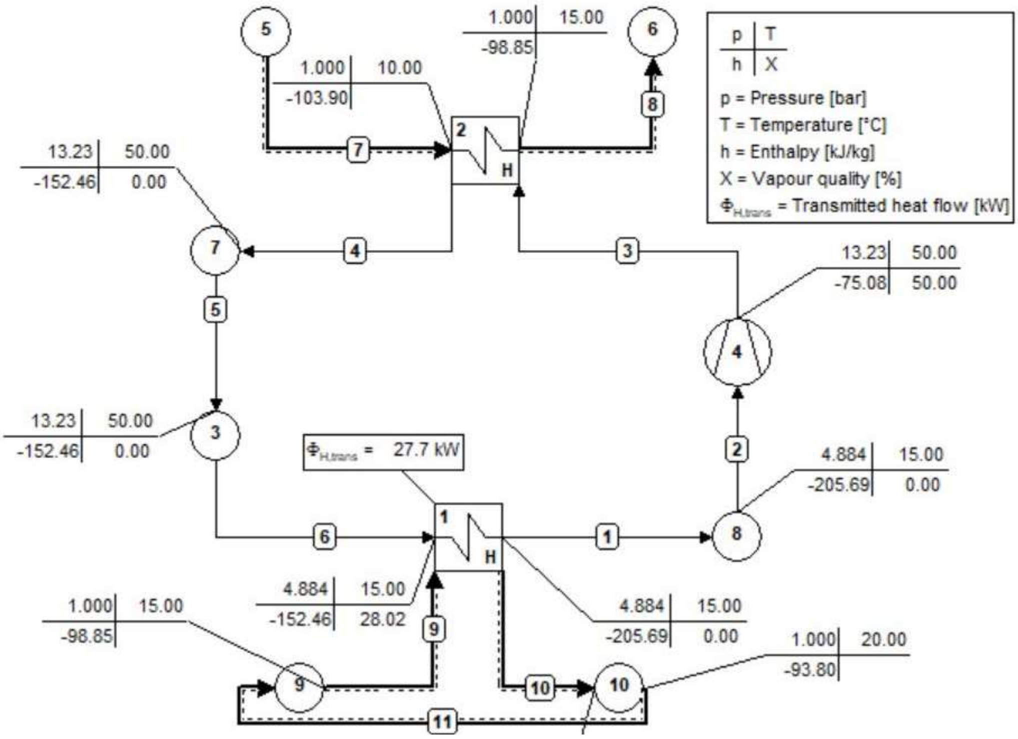

Fig 7.1: WET AFTER COMPRESSION

The figure 7.1 states "Wet after compression" in an HVAC system refers to a condition where the refrigerant exiting the compressor contains liquid or is partially saturated. This condition is undesirable as it can lead to reduced cooling capacity, potential damage to the compressor, decreased system efficiency, and oil dilution. It occurs when the refrigerant hasn't fully transitioned into a gas due to factors like inadequate heat removal or excessive refrigerant flow.

2.Dry After Compression

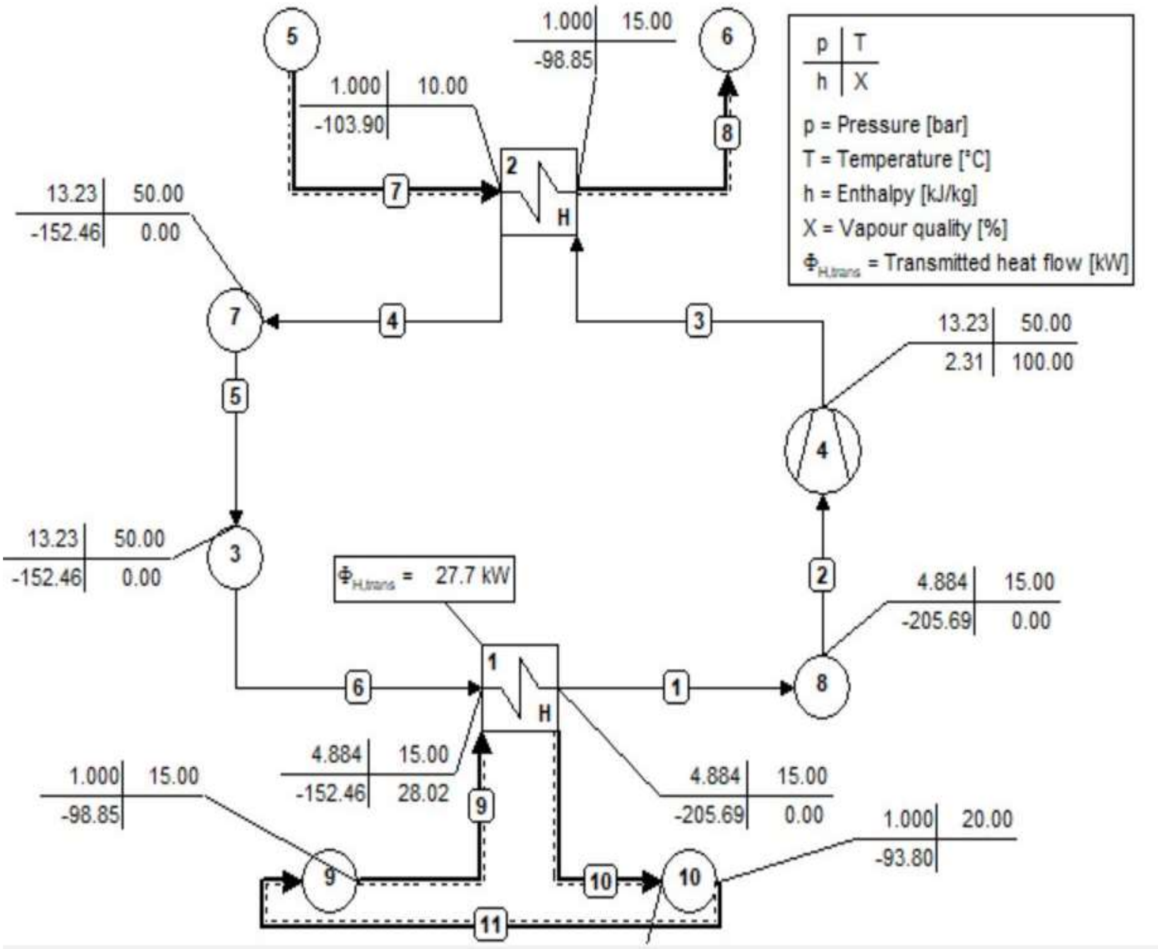

Fig 7.2: WET AFTER COMPRESSION

"Dry after compression" in an HVAC system refers the figure 7.2 to a desirable condition where the refrigerant exiting the compressor is completely vaporized and contains no liquid. This means that the refrigerant has effectively transitioned into a gas, ensuring optimal system performance. Dry compression is important for maintaining cooling capacity, preventing damage to the compressor, maximizing system efficiency, and avoiding oil dilution.

3.SuperHeat After Compression

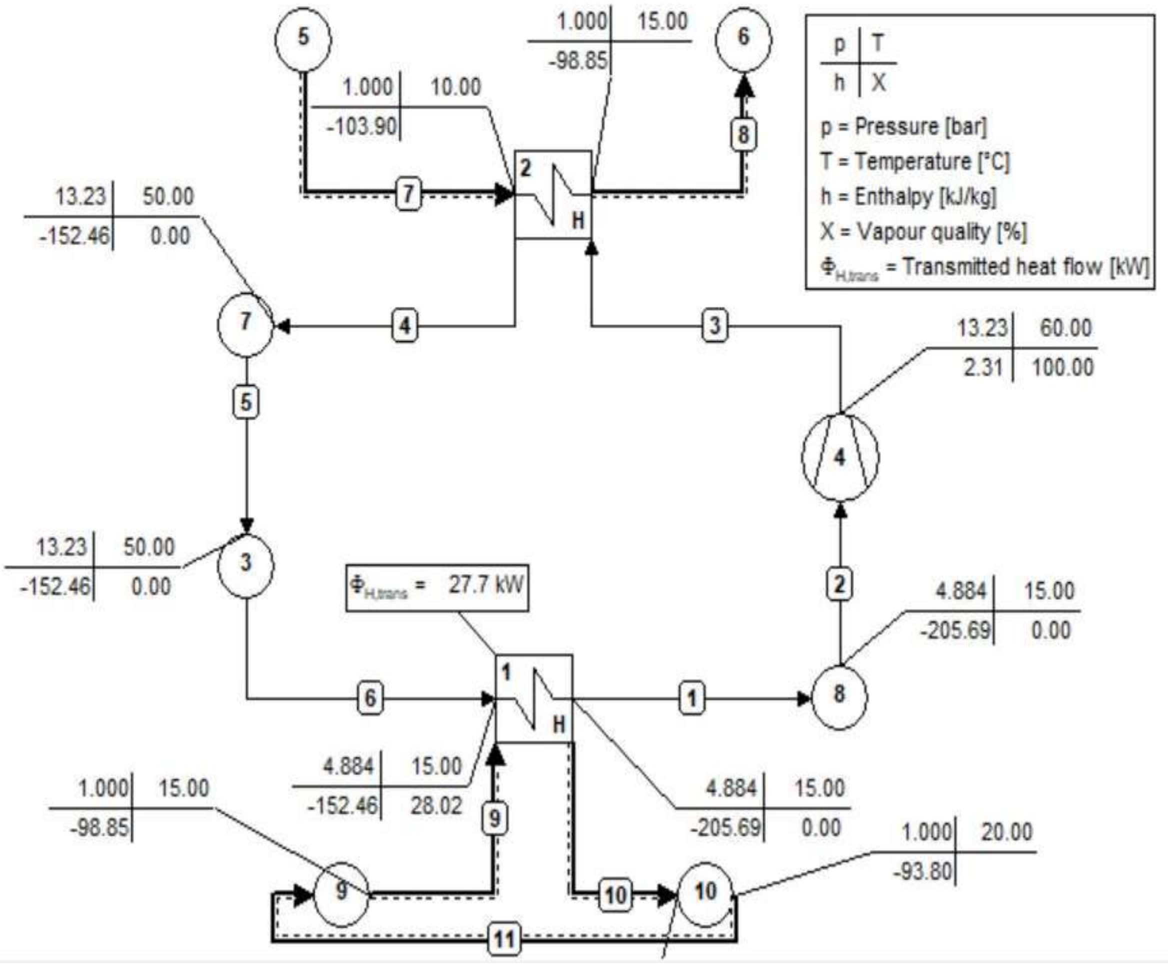

Fig 7.3: SUPERHEAT AFTER COMPRESSION

The figure 7.3 shows "Superheat after compression" in an HVAC system refers to a condition where the temperature of the refrigerant vapor leaving the compressor is higher than its saturation temperature at the corresponding pressure. This means that the refrigerant has absorbed additional heat energy beyond what is necessary for vaporization. Superheat is desirable as it ensures that the refrigerant is in a fully gaseous state, which prevents liquid droplets from entering the system and damaging components.

4: Superheat Before Compression

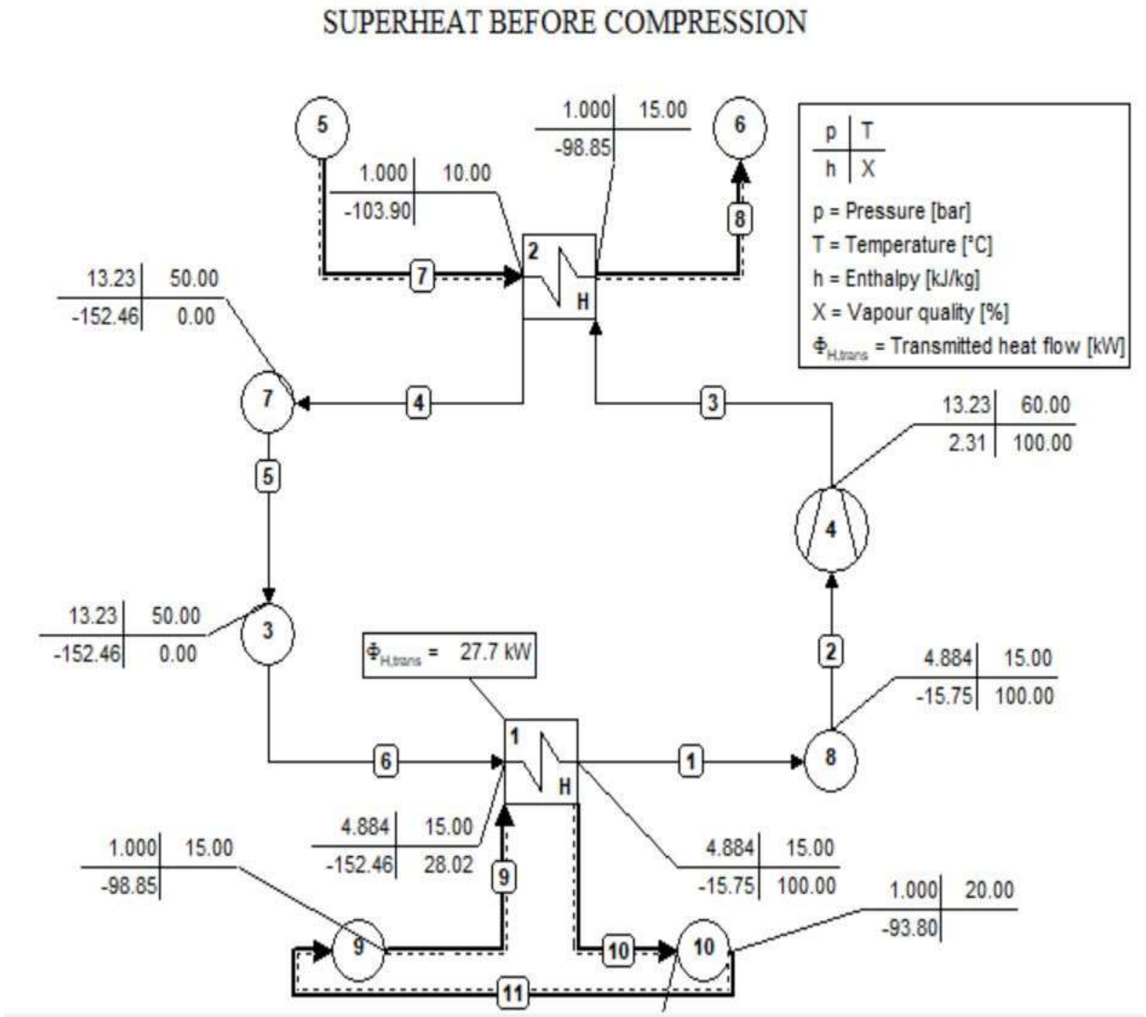

Fig 7.4: SUPERHEAT BEFORE COMPRESSION

The figure 7.4 shows "Superheat before compression" in an HVAC system refers to a condition where the refrigerant vapor entering the compressor has a higher temperature than its saturation temperature at the corresponding pressure. This means that the refrigerant has absorbed additional heat energy before reaching the compressor. Superheat before compression is generally undesired as it can lead to increased compressor workload and decreased system efficiency. Proper control of superheat levels through proper system design and adjustment of expansion valves is crucial for optimal performance and to avoid potential compressor overheating and damage

Simulation for various refrigerant is done by considering the same thermal load for all the refrigerant.

REFRIGERANT	COMPRESSOR WORK (KW)	COP
R134a	8.16	3.4
R142b	7.57	3.65
Ammonia	2.43	11.3
Benzene	5.22	5.3

Table 7.1 Comparative Study of Various Refrigerant

R134a: R134a, also known as Tetrafluoroethane, is a common hydrofluorocarbon (HFC) refrigerant. It has good thermodynamic properties and is widely used in commercial and automotive air conditioning systems, providing a relatively high COP as shown in table 7.1.

R142b: R142b, known as Chlorodifluoromethane, is another HFC refrigerant. It has a lower global warming potential (GWP) compared to R134a but is not as commonly used. R142b offers moderate thermodynamic properties and can be an alternative to R134a in certain applications.

Benzene: Benzene is an organic compound used as a refrigerant in some older systems. However, due to its high toxicity and flammability, its use has been phased out in most modern HVAC systems. Benzene has a low COP and is not considered a suitable refrigerant option today.

Ammonia: Ammonia (NH_3) is a natural refrigerant widely recognized for its high efficiency. It offers excellent thermodynamic properties, including a low boiling point, high latent heat of vaporization, and minimal temperature glide. Ammonia has the highest COP among the listed refrigerants and is commonly used in large industrial refrigeration and HVAC systems.

7.1 HVAC system for summer Cooling

A simple refrigerant 134a (tetrafluoroethene) heat pump for space heating. operates between temperature limits of 15 deg * C and 50°C. assuming the specific heat of vapour as 0.996 kJ / kg* K; The C.O.P The specific volume of refrigerant 134a saturated pour at 15°C is 0.04185.

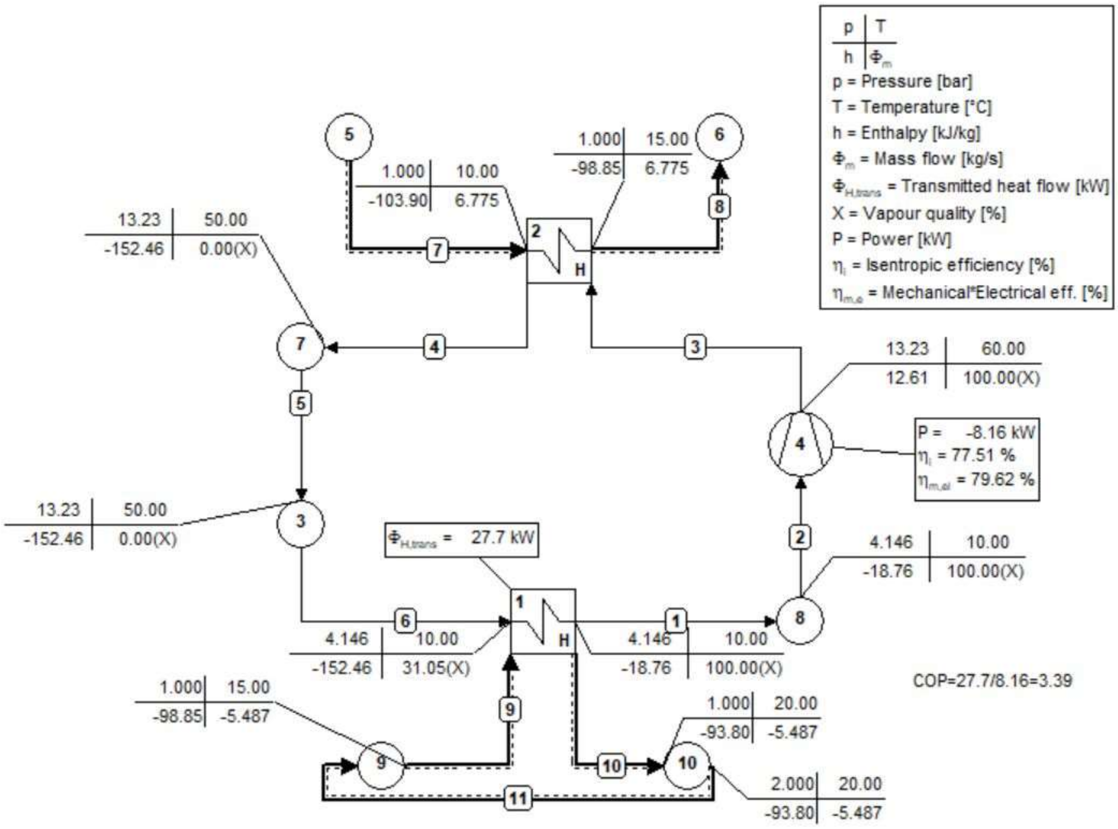

Fig 7.5: HVAC System for Summer Cooling

The simulated cycle of normal HVAC system for summer cooling in Cycle Tempo software using the above problem statement. The figure 7.5 shows us the actual cycle tempo cycle and its outputs after a successful simulation it includes temperature, pressure, enthalpy, quality and work done.

7.2 Modified HVAC system for summer cooling using ground source

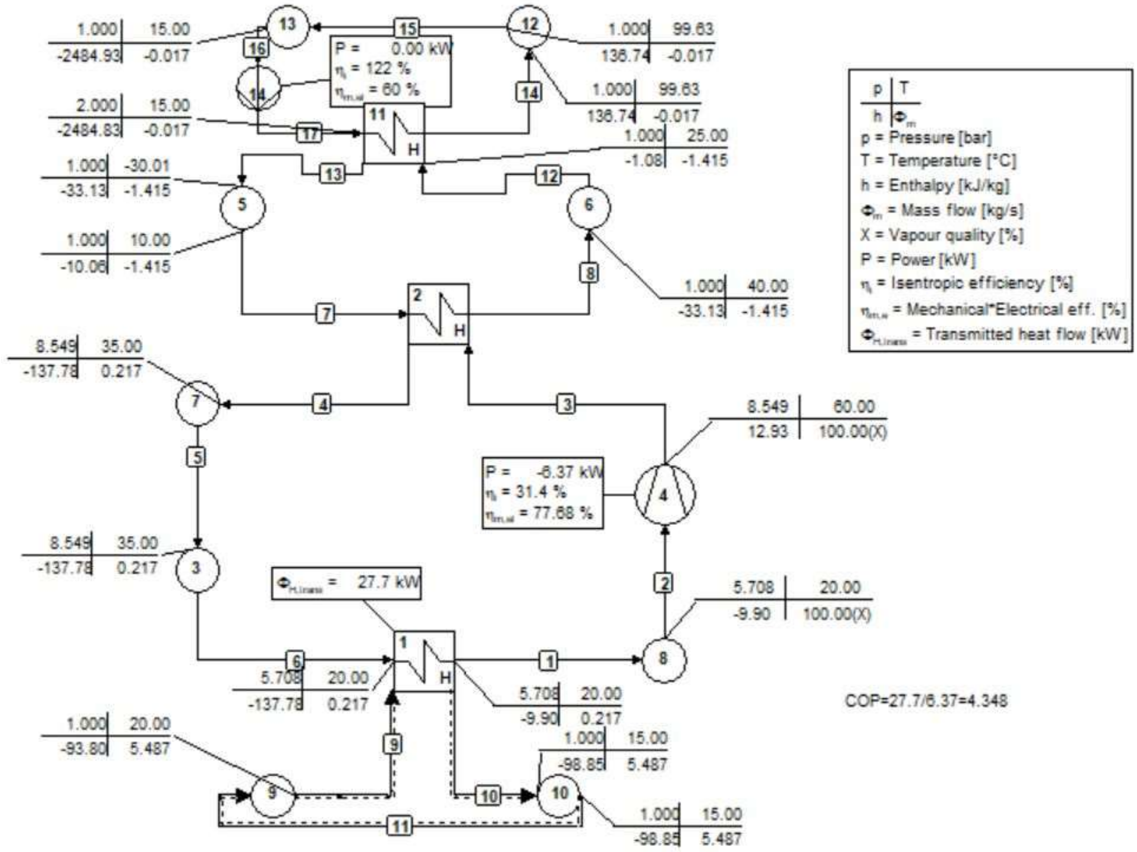

Fig 7.6: GSPH connected HVAC system for Summer Cooling

The simulated cycle of GSPH connected HVAC system for summer cooling in Cycle Tempo software using the above problem statement. The figure 7.6 shows us the actual cycle tempo cycle and its outputs after a successful simulation it includes temperature, pressure, enthalpy, quality and work done.

7.3 Comparison of normal summer cooling HVAC system with the modified geothermal attached summer cooling HVAC system.

Parameters	Summer Cooling	Summer Cooling with Geothermal
Temp at point 1	10^0c	10^0c
Temp at point 2	60^0c	60^0c
Temp at point 3	40^0c	35^0c
Temp at point 4	10^0c	10^0c
Pressure at point 1 (bar)	4.146	4.25
Pressure at point 2 (bar)	13.23	9.7
Pressure at point 3 (bar)	13.23	9.7
Pressure at point 4 (bar)	4.146	4.25
Quality (X) at point 1	1	1
Quality (X) at point 2	1	1
Quality (X) at point 3	0	0
Quality (X) at point 4	0.31	0.2
Compressor work	8.16	6.37
COP	3.4	4.34
Percentage saving in power for the compressor	21.93%	

Table 7.2: Summer cooling HVAC System with Modified GSPH

The table 7.2 gives the comparative study of the pressure, temperature quality and COP of the normal HVAC system and modified HVAC system for summer cooling. stated the percentage saving in power for the compressor of 21.93% because of modification done in the condenser part of the HVAC system.

7.4 HVAC System for Winter Heating

A simple refrigerant 134a (tetrafluoroethene) heat pump for space heating. operates between temperature limits of 15 deg * C and 50°C. The heat required to be pumped is 100 MJ. assuming the specific heat of vapour as 0.996 kJ / kg* K. The C.O.P The specific volume of refrigerant 134a saturated pour at 15°C is 0.04185.

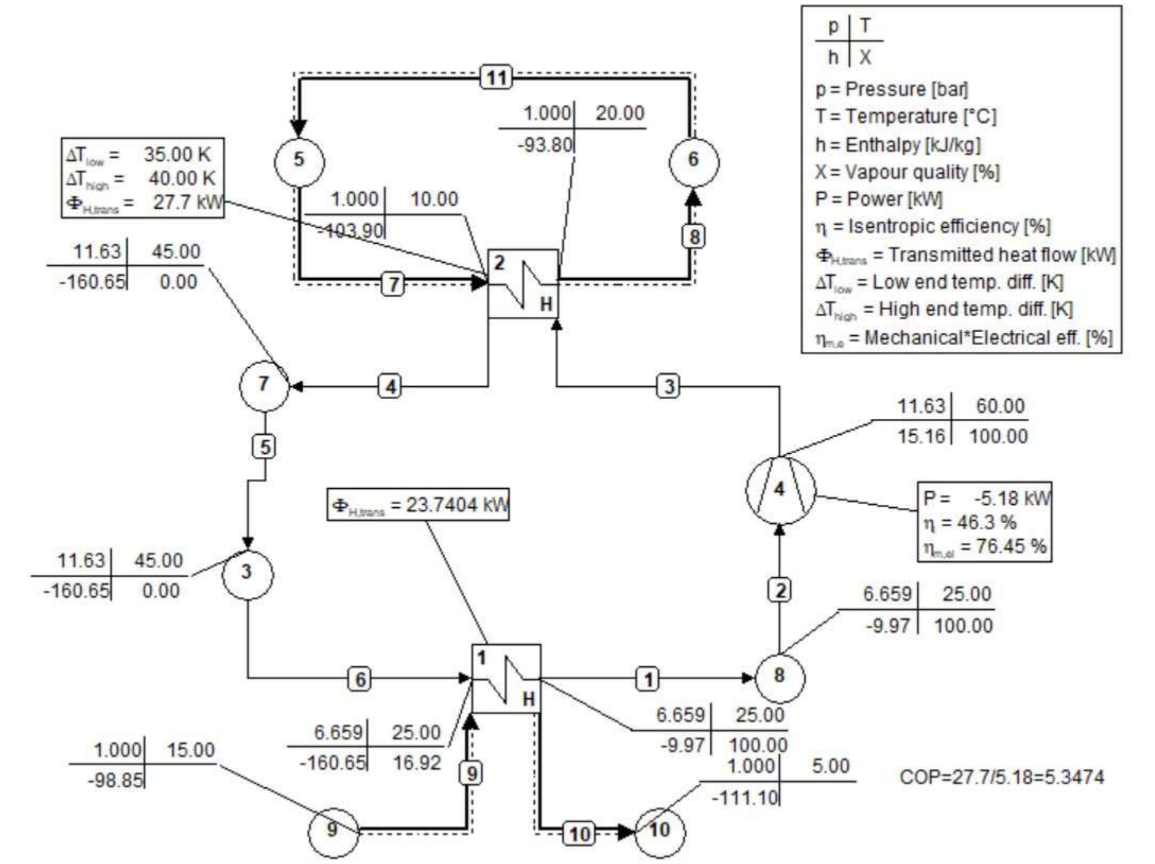

Fig 7.7: HVAC System for Winter Heating

The simulated cycle of normal HVAC system for Winter heating in Cycle Tempo software using the above problem statement. The figure 7.7 shows us the actual cycle tempo cycle and its outputs after a successful simulation it includes temperature, pressure, enthalpy, quality and work done.

7.5 Modified HVAC System for Winter Heating using ground source.

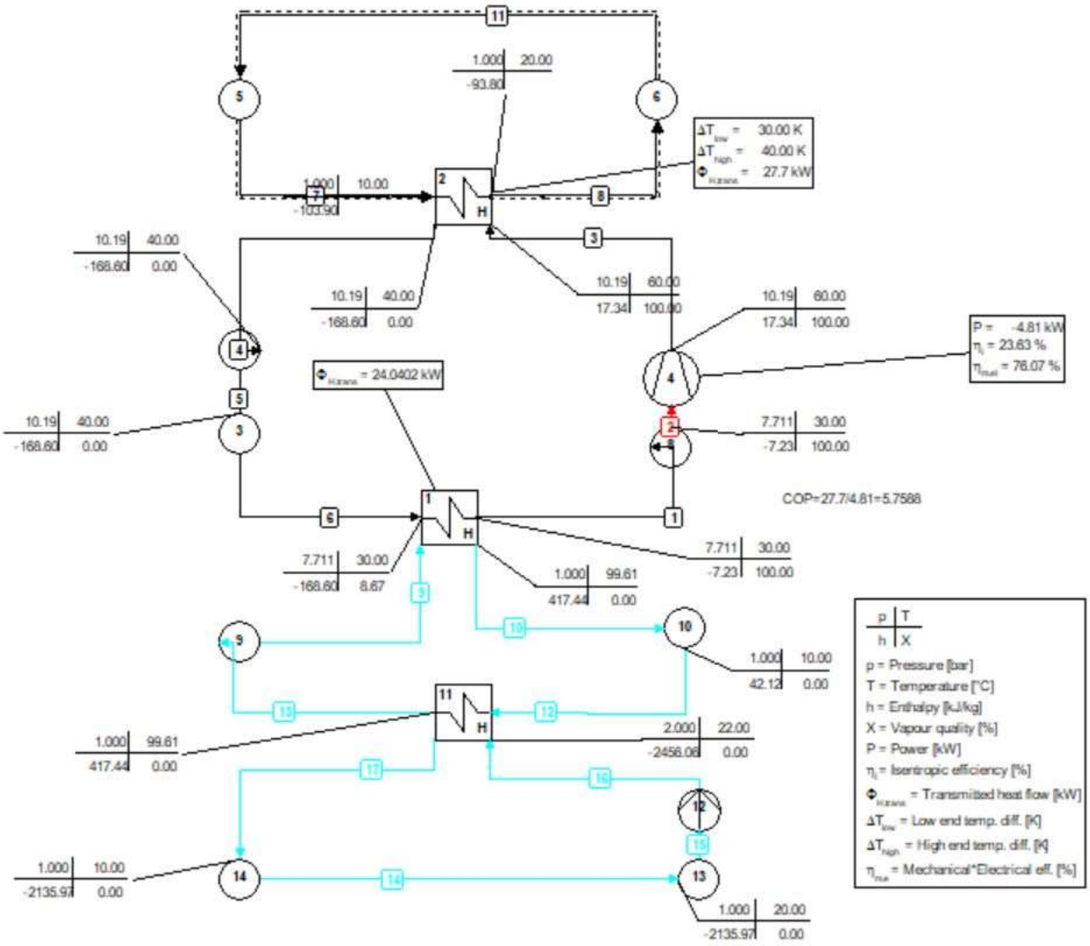

Fig 7.8: GSPH connected HVAC system for Winter Heating

The simulated cycle of GSPH connected HVAC system for Winter heating in Cycle Tempo software using the above problem statement. The figure 7.8 shows us the actual cycle tempo cycle and its outputs after a successful simulation it includes temperature, pressure, enthalpy, quality and work done.

7.6 Comparison of normal winter heating HVAC with the modified geothermal attached winter heating HVAC system

Parameters	Winter Heating	Winter Heating with Geothermal
Temp at point 1	45^0c	40^0c
Temp at point 2	20^0c	30^0c
Temp at point 3	23.22^0c	30^0c
Temp at point 4	60^0c	60^0c
Pressure at point 1 (bar)	11.63	10.19
Pressure at point 2 (bar)	6.65	7.71
Pressure at point 3 (bar)	6.65	7.71
Pressure at point 4 (bar)	11.63	10.19
Quality (X) at point 1	0	0
Quality (X) at point 2	0.36	0.086
Quality (X) at point 3	1	1
Quality (X) at point 4	1	1
Compressor work	5.18	4.81
COP	5.3	5.75
Percentage saving in power for the compressor	8.5%	

Table 7.3: Winter Heating HVAC System with Modified GSPH

The above table 7.3 gives the comparative study of the pressure, temperature quality and COP of the normal HVAC system and modified HVAC system for winter heating and also stated the percentage saving in power for the compressor is 8.5% because of modification done in the condenser part of the HVAC system.

We have used the concept of Superheating is a technique used in HVAC (Heating, Ventilation, and Air Conditioning) systems to enhance the performance and efficiency of the system. It involves heating the refrigerant above its saturation point to a higher temperature, ensuring that it remains in a gaseous state throughout the cooling process. This is achieved by passing the refrigerant through a superheated coil or chamber.

Reasons to Use Superheating in HVAC Systems:

1.Increased efficiency: Superheating allows for better heat transfer and improved overall efficiency of the HVAC system.
2.Enhanced cooling capacity: By superheating the refrigerant, the system can extract more heat from the conditioned space, leading to better cooling capacity.
3.Better humidity control: Superheating helps in dehumidification by increasing the ability of the system to remove moisture from the air.
4.Reduced energy consumption: Improved efficiency and cooling capacity result in lower energy consumption, leading to cost savings.
5.Improved system performance: Superheating optimizes the system's performance by maintaining the refrigerant in a gaseous state, preventing liquid refrigerant from entering the compressor.
6.Avoidance of compressor damage: Superheating helps protect the compressor from potential damage caused by liquid refrigerant entering it.
7.Temperature control precision: The use of superheating allows for better control over the refrigerant's temperature, ensuring accurate temperature regulation.
8.Flexibility in system design: Superheating provides flexibility in designing HVAC systems, allowing for longer refrigerant lines and increased system efficiency.
9.Compatibility with low-temperature applications: Superheating is particularly beneficial in low-temperature applications where achieving proper cooling is crucial.
10.Improved air quality: Superheating can contribute to better indoor air quality by aiding in moisture removal and preventing mould growth.t of Superheating and subcooling for our problem statement to get different COP and possible working conditions.

Subcooling is an important concept in HVAC (Heating, Ventilation, and Air Conditioning) systems that involves cooling the refrigerant below its saturation point, ensuring it remains in a liquid state throughout the refrigeration cycle. This is achieved by removing heat from the refrigerant after it has undergone condensation.

Reasons to Use Subcooling in HVAC Systems:

1.Improved efficiency: Subcooling increases the overall efficiency of the HVAC system by removing additional heat from the refrigerant, resulting in better heat transfer.

2.Enhanced refrigerant capacity: Subcooling allows the system to store more refrigerant, increasing its cooling capacity and efficiency.

3.Prevention of flash gas: Subcooling reduces the likelihood of flash gas formation by ensuring the refrigerant remains in a liquid state, minimizing the risk of compressor damage.

4.Better system performance: Subcooling optimizes the system's performance by maintaining the refrigerant in a fully liquid state before it enters the expansion device.

5.Energy savings: Improved efficiency through subcooling leads to reduced energy consumption, resulting in cost savings over time.

6.Increased compressor reliability: Subcooling helps protect the compressor from potential damage caused by the presence of vapor or refrigerant slugging, improving its reliability and lifespan.

7.Precise temperature control: Subcooling assists in achieving accurate temperature control in the conditioned space, enhancing comfort levels.

8.Improved heat transfer: Subcooling enhances the system's ability to transfer heat, allowing for more efficient cooling and dehumidification.

9.Compatibility with high-temperature applications: Subcooling is particularly beneficial in high-temperature environments where maintaining optimal cooling is critical.

10.Extended equipment life: By ensuring the refrigerant remains in a liquid state, subcooling helps prevent excessive wear and tear on HVAC equipment, prolonging its lifespan.

Chapter 8: Results and Discussion

8.1 Simulation of entire HVAC system for different conditions:

The following are the conditions for testing the cycle tempo model of the developed system they are as follows:

1. Degree of superheat 10 degree
2. Degree of superheat 10 degree
3. Degree of superheat 10 degree
4. Degree of superheat 10 degree and Degree of subcooling 10 degree
5. Degree of superheat 10 degree and Degree of subcooling 20 degree
6. Degree of superheat 10 degree and Degree of subcooling 30 degree
7. Degree of superheat 20 degree and Degree of subcooling 10 degree
8. Degree of superheat 20 degree and Degree of subcooling 20 degree
9. Degree of superheat 20 degree and Degree of subcooling 30 degree
10. Degree of superheat 30 degree and Degree of subcooling 10 degree
11. Degree of superheat 30 degree and Degree of subcooling 20 degree
12. Degree of superheat 30 degree and Degree of subcooling 30 degree

1.Degree of superheat 10 degree

Parameters	Summer Cooling	Summer Cooling with Geothermal
Temp at point 1	10^0C	10^0C
Temp at point 2	60^0C	70^0C
Temp at point 3	50^0C	50^0C
Temp at point 4	10^0C	10^0C
Pressure at point 1 (bar)	4.146	4.25
Pressure at point 2 (bar)	13.23	12.32
Pressure at point 3 (bar)	13.23	12.32
Pressure at point 4 (bar)	4.146	4.25
Quality (X) at point 1	1	1
Quality (X) at point 2	1	1
Quality (X) at point 3	0	0
Quality (X) at point 4	0.31	0.2
Compressor work	8.16	7.41
COP	3.4	3.73
Percentage saving in power for the compressor	9.19%	

Table 8.1: Degree of superheat 10 degree

The table 8.1 gives the comparative study of the pressure, temperature quality and COP of the normal HVAC system and modified HVAC system for summer cooling at a 10-degree superheat. Stated the percentage saving in power for the compressor of 9.19% because of modification done in the condenser part of the normal HVAC system.

2.Degree of superheat 20 degree

Parameters	Summer Cooling	Summer Cooling with Geothermal
Temp at point 1	10^0C	10^0C
Temp at point 2	70^0C	70^0C
Temp at point 3	50^0C	50^0C
Temp at point 4	10^0C	10^0C
Pressure at point 1 (bar)	4.146	4.25
Pressure at point 2 (bar)	13.23	12.32
Pressure at point 3 (bar)	13.23	12.32
Pressure at point 4 (bar)	4.146	4.25
Quality (X) at point 1	1	1
Quality (X) at point 2	1	1
Quality (X) at point 3	0	0
Quality (X) at point 4	0.31	0.28
Compressor work	10.48	9.48
COP	2.63	2.98
Percentage saving in power for the compressor	9.54%	

Table 8.2: Degree of superheat 20 degree

The table 8.2 gives the comparative study of the pressure, temperature quality and COP of the normal HVAC system and modified HVAC system for summer cooling at 20-degree superheat temperature. Stated the percentage saving in power for the compressor of 9.54% because of modification done in the condenser part of the HVAC system.

3.Degree of superheat 30 degree

Parameters	Summer Cooling	Summer Cooling with Geothermal
Temp at point 1	10^0C	10^0C
Temp at point 2	80^0C	80^0C
Temp at point 3	50^0C	50^0C
Temp at point 4	10^0C	10^0C
Pressure at point 1 (bar)	4.146	4.25
Pressure at point 2 (bar)	13.23	12.32
Pressure at point 3 (bar)	13.23	12.32
Pressure at point 4 (bar)	4.146	4.25
Quality (X) at point 1	1	1
Quality (X) at point 2	1	1
Quality (X) at point 3	0	0
Quality (X) at point 4	0.31	0.28
Compressor work	12.78	11.43
COP	2.16	2.42
Percentage saving in power for the compressor	10.56%	

Table 8.3: Degree of superheat 30 degree

The table 8.3 gives the comparative study of the pressure, temperature quality and COP of the normal HVAC system and modified HVAC system for summer cooling at 30 degree superheat. stated the percentage saving in power for the compressor of 10.56% because of modification done in the condenser part of the HVAC system.

4.Degree of superheat 10 degree and Degree of subcooling 10 degree

Parameters	Summer Cooling	Summer Cooling with Geothermal
Temp at point 1	10^0C	10^0C
Temp at point 2	60^0C	60^0C
Temp at point 3	40^0C	40^0C
Temp at point 4	10^0C	10^0C
Pressure at point 1 (bar)	4.146	4.25
Pressure at point 2 (bar)	13.23	12.32
Pressure at point 3 (bar)	13.23	12.32
Pressure at point 4 (bar)	4.146	4.25
Quality (X) at point 1	1	1
Quality (X) at point 2	1	1
Quality (X) at point 3	0	0
Quality (X) at point 4	0.31	0.2
Compressor work	7.36	6.77
COP	3.76	4.09
Percentage saving in power for the compressor	8.01%	

Table 8.4: Degree of superheat 10 degree and Degree of subcooling 10 degree

The table 8.4 gives the comparative study of the pressure, temperature quality and COP of the normal HVAC system and modified HVAC system for summer cooling at 10-degree super heat and 10 degree subcooling. stated the percentage saving in power for the compressor of 8.01% because of modification done in the condenser part of the HVAC system.

5.Degree of superheat 20 degree and Degree of subcooling 10 degree

Parameters	Summer Cooling	Summer Cooling with Geothermal
Temp at point 1	10^0C	10^0C
Temp at point 2	70^0C	70^0C
Temp at point 3	40^0C	40^0C
Temp at point 4	10^0C	10^0C
Pressure at point 1 (bar)	4.146	4.25
Pressure at point 2 (bar)	13.23	12.32
Pressure at point 3 (bar)	13.23	12.32
Pressure at point 4 (bar)	4.146	4.25
Quality (X) at point 1	1	1
Quality (X) at point 2	1	1
Quality (X) at point 3	0	0
Quality (X) at point 4	0.31	0.2
Compressor work	9.48	8.68
COP	2.98	3.19
Percentage saving in power for the compressor	8.43%	

Table 8.5 : Degree of superheat 20 degree and Degree of sub cooling 10 degree

The table 8.5 gives the comparative study of the pressure, temperature quality and COP of the normal HVAC system and modified HVAC system for summer cooling at 20 degree super heat and 10 degree subcooling. stated the percentage saving in power for the compressor of 8.43% because of modification done in the condenser part of the HVAC system.

6.Degree of superheat 20 degree and Degree of sub cooling 20 degree

Parameters	Summer Cooling	Summer Cooling with Geothermal
Temp at point 1	10^0C	10^0C
Temp at point 2	70^0C	70^0C
Temp at point 3	30^0C	30^0C
Temp at point 4	10^0C	10^0C
Pressure at point 1 (bar)	4.146	4.25
Pressure at point 2 (bar)	13.23	12.32
Pressure at point 3 (bar)	13.23	12.32
Pressure at point 4 (bar)	4.146	4.25
Quality (X) at point 1	1	1
Quality (X) at point 2	1	1
Quality (X) at point 3	0	0
Quality (X) at point 4	0.31	0.13
Compressor work	8.70	8.03
COP	3.18	3.45
Percentage saving in power for the compressor	7.70%	

Table 8.6: Degree of superheat 20 degree and Degree of sub cooling 20 degree

The table 8.6 gives the comparative study of the pressure, temperature quality and COP of the normal HVAC system and modified HVAC system for summer cooling at 20 degree super heat and 20 degree subcooling. stated the percentage saving in power for the compressor of 7.70% because of modification done in the condenser part of the HVAC system.

7.Degree of superheat 20 degree and Degree of sub cooling 30 degree

Parameters	Summer Cooling	Summer Cooling with Geothermal
Temp at point 1	10^0C	10^0C
Temp at point 2	70^0C	70^0C
Temp at point 3	20^0C	20^0C
Temp at point 4	10^0C	10^0C
Pressure at point 1 (bar)	4.146	4.25
Pressure at point 2 (bar)	13.23	12.32
Pressure at point 3 (bar)	13.23	12.32
Pressure at point 4 (bar)	4.146	4.25
Quality (X) at point 1	1	1
Quality (X) at point 2	1	1
Quality (X) at point 3	0	0
Quality (X) at point 4	0.31	0.06
Compressor work	8.06	7.5
COP	3.4	3.7
Percentage saving in power for the compressor	6.94%	

Table 8.7: Degree of superheat 20 degree and Degree of sub cooling 30 degree

The table 8.7 gives the comparative study of the pressure, temperature quality and COP of the normal HVAC system and modified HVAC system for summer cooling at 20 degree super heat and 30 degree subcooling. stated the percentage saving in power for the compressor of 6.94% because of modification done in the condenser part of the HVAC system.

8.Degree of superheat 30 degree and Degree of sub cooling 10 degree

Parameters	Summer Cooling	Summer Cooling with Geothermal
Temp at point 1	10^0C	10^0C
Temp at point 2	80^0C	80^0C
Temp at point 3	40^0C	40^0C
Temp at point 4	10^0C	10^0C
Pressure at point 1 (bar)	4.146	4.25
Pressure at point 2 (bar)	13.23	12.32
Pressure at point 3 (bar)	13.23	12.32
Pressure at point 4 (bar)	4.146	4.25
Quality (X) at point 1	1	1
Quality (X) at point 2	1	1
Quality (X) at point 3	0	0
Quality (X) at point 4	0.31	0.2
Compressor work	11.48	10.49
COP	2.4	2.64
Percentage saving in power for the compressor	8.62%	

Table 8.8: Degree of superheat 30 degree and Degree of sub cooling 10 degree

The table 8.8 gives the comparative study of the pressure, temperature quality and COP of the normal HVAC system and modified HVAC system for summer cooling at 30 degree super heat and 10 degree subcooling. stated the percentage saving in power for the compressor of 8.62% because of modification done in the condenser part of the HVAC system.

9.Degree of superheat 30 degree and Degree of sub cooling 20 degree

Parameters	Summer Cooling	Summer Cooling with Geothermal
Temp at point 1	10^0C	10^0C
Temp at point 2	80^0C	80^0C
Temp at point 3	30^0C	30^0C
Temp at point 4	10^0C	10^0C
Pressure at point 1 (bar)	4.146	4.25
Pressure at point 2 (bar)	13.23	12.32
Pressure at point 3 (bar)	13.23	12.32
Pressure at point 4 (bar)	4.146	4.25
Quality (X) at point 1	1	1
Quality (X) at point 2	1	1
Quality (X) at point 3	0	0
Quality (X) at point 4	0.31	0.13
Compressor work	10.55	9.73
COP	2.6	2.84
Percentage saving in power for the compressor	7.77%	

Table 8.9: Degree of superheat 30 degree and Degree of sub cooling 20 degree

The table 8.9 gives the comparative study of the pressure, temperature quality and COP of the normal HVAC system and modified HVAC system for summer cooling at 30 degree super heat and 20 degree subcooling. stated the percentage saving in power for the compressor of 7.77% because of modification done in the condenser part of the HVAC system.

10.Degree of superheat 30 degree and Degree of sub cooling 30 degree

Parameters	Summer Cooling	Summer Cooling with Geothermal
Temp at point 1	10^0C	10^0C
Temp at point 2	80^0C	80^0C
Temp at point 3	20^0C	20^0C
Temp at point 4	10^0C	10^0C
Pressure at point 1 (bar)	4.146	4.25
Pressure at point 2 (bar)	13.23	12.32
Pressure at point 3 (bar)	13.23	12.32
Pressure at point 4 (bar)	4.146	4.25
Quality (X) at point 1	1	1
Quality (X) at point 2	1	1
Quality (X) at point 3	0	0
Quality (X) at point 4	0.31	0.06
Compressor work	9.81	9.09
COP	2.8	3.05
Percentage saving in power for the compressor	7.33%	

Table 8.10: Degree of superheat 30 degree and Degree of sub cooling 30 degree

The table 8.10 gives the comparative study of the pressure, temperature quality and COP of the normal HVAC system and modified HVAC system for summer cooling at 30 degree superheat and 30 degree subcooling. stated the percentage saving in power for the compressor of 7.33% because of modification done in the condenser part of the HVAC system.

11.Degree of superheat 10 degree and Degree of sub cooling 20 degree

Parameters	Summer Cooling	Summer Cooling with Geothermal
Temp at point 1	10^0C	10^0C
Temp at point 2	60^0C	60^0C
Temp at point 3	20^0C	20^0C
Temp at point 4	10^0C	10^0C
Pressure at point 1 (bar)	4.146	4.25
Pressure at point 2 (bar)	13.23	12.32
Pressure at point 3 (bar)	13.23	12.32
Pressure at point 4 (bar)	4.146	4.25
Quality (X) at point 1	1	1
Quality (X) at point 2	1	1
Quality (X) at point 3	0	0
Quality (X) at point 4	0.31	0.2
Compressor work	6.23	5.82
COP	4.4	4.76
Percentage saving in power for the compressor	6.58%	

Table 8.11: Degree of superheat 10 degree and Degree of sub cooling 20 degree

The table 8.11 gives the comparative study of the pressure , temperature quality and COP of the normal HVAC system and modified HVAC system for summer cooling at 10 degree super heat and 20 degree subcooling . stated the percentage saving in power for the compressor of 6.58% because of modification done in the condenser part of the HVAC system.

12.Degree of superheat 10 degree and Degree of sub cooling 30 degree

Parameters	Summer Cooling	Summer Cooling with Geothermal
Temp at point 1	10^0C	10^0C
Temp at point 2	60^0C	60^0C
Temp at point 3	30^0C	30^0C
Temp at point 4	10^0C	10^0C
Pressure at point 1 (bar)	4.146	4.25
Pressure at point 2 (bar)	13.23	12.32
Pressure at point 3 (bar)	13.23	12.32
Pressure at point 4 (bar)	4.146	4.25
Quality (X) at point 1	1	1
Quality (X) at point 2	1	1
Quality (X) at point 3	0	0
Quality (X) at point 4	0.31	0.13
Compressor work	6.73	6.25
COP	4.11	4.43
Percentage saving in power for the compressor	7.13%	

Table 8.12: Degree of superheat 10 degree and Degree of sub cooling 30 degree

The table 8.12 gives the comparative study of the pressure, temperature quality and COP of the normal HVAC system and modified HVAC system for summer cooling at 10-degree super heat and 30-degree subcooling. stated the percentage saving in power for the compressor of 7.13% because of modification done in the condenser part of the HVAC system.

CHAPTER 9: CONCLUSION

In conclusion, our project focused on simulating and analyzing various HVAC system conditions and configurations, including superheating, subcooling, and different refrigerant types. Also incorporated ground conditions into the study, specifically exploring ground source heat pumps (GSHP). Through simulations, system's performance is assessed and efficiency under different parameters, providing insights for system designers and engineers to optimize HVAC systems for specific requirements.

Our analysis compared different configurations and refrigerants, evaluating their impact on system performance. Additionally, it is also highlighted the energy-saving potential of GSHPs, utilizing the stable ground temperature as a heat source or sink. GSHPs demonstrated improved efficiency and reduced energy consumption compared to conventional HVAC systems, particularly in regions with moderate temperature variations.

By implementing GSHP technology, it offers a sustainable solution for heating and cooling needs, reducing greenhouse gas emissions and dependence on fossil fuels. This aligns with the goals of energy efficiency, cost reduction, and creating a comfortable interior environment.

In summary, our project provided valuable insights into HVAC system simulation and analysis, including the exploration of ground source heat pumps. It is also demonstrated that the potential for energy savings and environmental benefits through GSHP implementation. This research contributes to advancing sustainable and efficient HVAC systems, paving the way for a greener future in thermal sciences.

Moving forward, it is essential for the HVAC industry to embrace renewable energy sources and innovative technologies. Integrating renewables into HVAC systems, coupled with advancements in ground source heat pump technology, offers opportunities for energy savings, reduced carbon emissions, and a more sustainable future. By capitalizing on renewable energy and maximizing GSHP potential, we can create a greener, more efficient, and comfortable built environment.

CHAPTER 10: REFERENCES

[l] D. Coulomb, J. L. Dupont, A. Pichard, The Role of Refrigeration in the Global Economy, 29th Informatory Note on Refrigeration Tech- nologies, Technical, International Institute of Refrigeration, Paris, France 2015.

[2] International Energy Agency, The Future of Cooling, 2018, http://www.iea.org/reports/the-future-ofcooling , (accessed: November 2019).

[3] J. S. Brown, P. A. Domanski, Appl. Therm. Eng. 2014, 64, 252.

[4] D. R. Brown, T. B. Stout, J. A. Dirks, N. Fernandez, Energy Eng. 2012, 109, 7.

[5] International Institute of Refrigeration, http://www.iifiir.org/userfiles/file/webfiles/regulation files/Synthèse Kigali EN.pdf (accessed: November,2019).

[6] D. Enescu, E. O. Virjoghe, Renewable Sustainable Energy Rev. 2014,38, 903.

[7] 29L. K. Tartibu, Sustainable Energy Technol. Assess. 2019, 31, 102.

[8] K. Sainath, Mohd Aamer Khan, Faraz UR Rehman Azhar, Mohamad Ayazoddin4 , Mohd Abdul Omer Khan, Overview of “HVAC Systems” in General Aspects, IJRASET 2014.

[9] Mamdouh El Haj Assad, Maryam Nooman AlMallah, Ayman Ramadan, https://www.researchgate.net/publication/359388262_Geothermal_Heat_Pumps_Principles_and_Applications.

[10] Jeffrey Molavi , James McDaniel, A Review of the Benefits of Geothermal Heat Pump Systems in Retail Buildings, Procedia Engineering 145 (2016) 1135 – 1143.

[11] M.Soltani ,F.M.Kashkooli,A.R.Dehghani-Sanij,A.R KAzemi,A Comprehensive study of geothermal heating and cooling system,2018.

[12] Ioan Sarbu ,Calin Sebarchievici ,General review ground source heat pump system for heating and cooling of buildings,2013.

[13] Jin Luoa,, Joachim Rohnb, Wei Xianga, David Bertermannb, Philipp Blumc, A review of ground investigations for ground source heat pump (GSHP) systems,2016.

[14] Hüseyin Benli, A performance comparison between a horizontal source and a vertical source heat pump systems for a greenhouse heating in the mild climate Elazig, Turkey,2013.

[15] Mohamad Kharseh a , Lobna Altorkmany , Mohammed Al-Khawaja , Ferri Hassani, Analysis of the effect of global climate change on ground source heat pump systems in different climate categories,2015.

[16] Wei Wu, Baolong Wang, Tian You, Wenxing Shi, Xianting Li, A potential solution for thermal imbalance of ground source heat pump systems in cold regions: Ground source absorption heat pump,2013.

[17] Yuehong Bi a,c, Xinhong Wang a , Yun Liu a , Hua Zhang b , Lingen Chen, Comprehensive exergy analysis of a ground-source heat pump system for both building heating and cooling modes,2009

[18] Claudia de Lourdes Duran Tapia, Analysis of Cost and Energy Performance of Geothermal Heat Pump Systems in Southern Louisiana,2017.

[19] Jin-Yong Lee, Current status of ground source heat pumps in Korea,2009.

[20] J.Lund,B.Sanner,L.Rybach,R.Curtis,Geothermal (Ground-Source) Heat Pumps a World Overview,(2004).

[21] Robin Curtis1, J. C. Kapil, P.K. Satyawali, A. Ganju and Sharad Marathe,A First for India-100w Borehole Based Geothermal Heat Pump System for space Heating in the Himalayas,2015

[22] R. Chargui a , H. Sammouda a , A. Farhat b, Geothermal heat pump in heating mode: Modeling and simulation on TRNSYS,2012.

[23] Jason E. Gentry, Jeffrey D. Spitler, Daniel E. Fisher, Xiaowei Xu, Simulation of Hybrid Ground Source Heat Pump Systems and Experimental Validation,2006

[24] I Ya Lvocich, A P Preobrazhenskiy, O N Choporov, Simulation of geothermal pump,2018.

[25] Daniel E.Fisher and Simon J .Rees,Modelling Ground Source Heat Pump System In Building Energy Simulation Program,2005.

[26] Daeho Kang1, and Heejin Cho, Modeling of central ground-source heat pump system in EnergyPlus,2016.

[27] Amanda Jo Pertzborn, Gregory Nellis, Sanford Klein, Research on Ground Source Heat Pump Design,2010.

[28] Suraj Mahadeo Shende, DESIGN OF COLD STORAGE, International Research Journal of Engineering and Technology (IRJET),2018.

[29] Nimish Dhepe, Raahul Krishna, A Review of the Advancements in Geothermal Heating and Cooling System, Journal of Alternate Energy Sources and Technologies,2017.

[30] Stuart j.Self, Bale.V.Reddy,Marc A.Rosen, Geothermal heat pump System :Status Review and comparison with other heating options,Elsevier,2012.

[31] G P Vasilyev, V F Gornov , M V Kolesova, A N Dmitriev , Geothermal heat pump systems in cold regions: efficiency improvement by use of ambient air,2019.

[32] Ramadan Bassiouny,Mohamed R.O.Ali,Mohamed K.Hassan,An idea to enhance the thermal performance of HDPE pipes used for ground Source application,Applied thermal Engineering[2016].

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