MATLAB SIMULATION OF NATURAL REFRIGERANT BASED HYBRID REFRIGERATION SYSTEM AND ITS PERFORMANCE OPTIMIZATION BY INTRODUCING SOLAR THERMAL ENERGY

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CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled "**Matlab Simulation of Natural Refrigerant Based Hybrid Refrigeration System and Its Performs Optimization By Introducing Solar Thermal Energy"** is a bonafide work carried out by **DEBOBRATA BISWAS** under the supervision and guidance for partial fulfillment of the requirement for Post Graduate Degree of Masters of Technology in Energy Science & Technology ,during the academic session of 2021-2023.

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I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of his Master of Technology in Engineering Science and Technology studies during academic session 2021-2023.All the information in this document have been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all materials and results that are not original to this work.

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DEDICATED

TO

MY PARENTS

MY TEACHERS

&

MY FRIENDS

LIST OF FIGURE

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Abbreviations

Nomenclature

HRS	Hybrid Refrigeration System
NRS	Normal Refrigeration System
SWHS	Solar Water Heating System
VCRS	Vapour Compression Refrigeration System
C.O.P	Co-efficient Of Performance
R600a	Isobutane
ODP	Ozone Depletion Layer
GWP	Global Warming Potential
UV	Ultra Violet
HC	Hydro Carbon
CFCs	Chlorofluorocarbons
HCFCs	Hydro chlorofluorocarbons
RE	Refrigeration Effect
TR	Ton of Refrigeration
LH	Latent Heat
SH	Sensible Heat
P-H graph	Pressure-Enthalpy graph
SE	Solar Heat
WH	Waste Heat

CONTENT

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION OF RENEWABLE ENERGY:

Renewable energy comes from nature's own ways of replenishing itself, which helps the environment in the long run. This type of energy comes from things like sunlight, wind, moving water, and heat from the Earth. These sources are always available and don't run out quickly. They help make our energy cleaner and more sustainable. Some forms of renewable energy, like sunlight and wind, are very good for the environment, but others like certain types of biomass (organic material) are not so good when we use them too much. We use renewable energy to make electricity, heat, and cool things. It's great for big projects and even in faraway places, especially in developing countries where energy is important for progress. It's often used together with making things run on electricity, and it helps us move heat, objects, and ideas toward a future that's better for the planet.

Between 2011 and 2021, renewable energy's ascent is evident, growing from 20% to 28% of global electricity production. Fossil fuels recede from 68% to 62%, and nuclear from 12% to 10%. Hydropower's share dips from 16% to 15%, whereas solar and wind surge from 2% to 10%. Biomass and geothermal energy claim 3%, up from 2%. A global shift takes shape with 3,146 gigawatts spread across 135 nations, and 156 countries shaping the path through renewable energy regulations.

1.2 COMMON SOURCES OF RENEWABLE ENERGY:

1.2.1 SOLAR ENERGY

Solar energy comes from the sun's heat and has been used for a really long time, even thousands of years ago, to do things like warm up, cook food, and dry stuff. Nowadays, we use it to make electricity, especially in faraway places and even in space. As technology has improved, it has become cheaper to use. Since the sun keeps shining, we can keep using it over and over, which is great for the environment, it stands as a renewable, eco-friendly alternative to non-renewable coal and oil.

Fig. 1.1 Solar Energy

1.2.2 WIND ENERGY

Wind power is the use of wind energy to generate useful work. Historically, wind power was used by sails, windmills and wind pumps, but today it is mostly used to generate electricity. This article only deals with wind power for electricity generation. Today, wind power is almost completely generated with wind turbines, generally grouped into wind farms and connected to the electrical grid. In 2022, wind supplied over 2000 TWh of electricity, which was over 7% of world electricity 1:58 and about 2% of world energy. Wind power is considered a sustainable, renewable energy source, and has a much smaller impact on the environment compared to burning fossil fuels. Wind power is variable, so it needs energy storage or other dispatchable generation energy sources to attain a reliable supply of electricity. Land-based (onshore) wind farms have a greater visual impact on the landscape than most other power stations per energy produced.

Fig 1.2 Wind energy

1.2.3 BIO ENERGY

Bioenergy comes from the remains of plants and other living things. These sources include wood, crops like corn, special plants grown for energy, and waste from forests, yards, and farms. It's considered renewable because it comes from things that can grow again. Bioenergy can either help reduce or add to the gases that cause climate change. The most common type of bioenergy comes from wood and leftover plant bits. We can use wood as fuel or make small pieces called pellets. Other plants like corn, switch grass, and bamboo can also be used. Even leftover materials like wood, farm waste, and things we don't need can be turned into this type of energy. To make bioenergy better, we can use different methods to change it into more powerful fuels, like using heat, chemicals, or special processes.

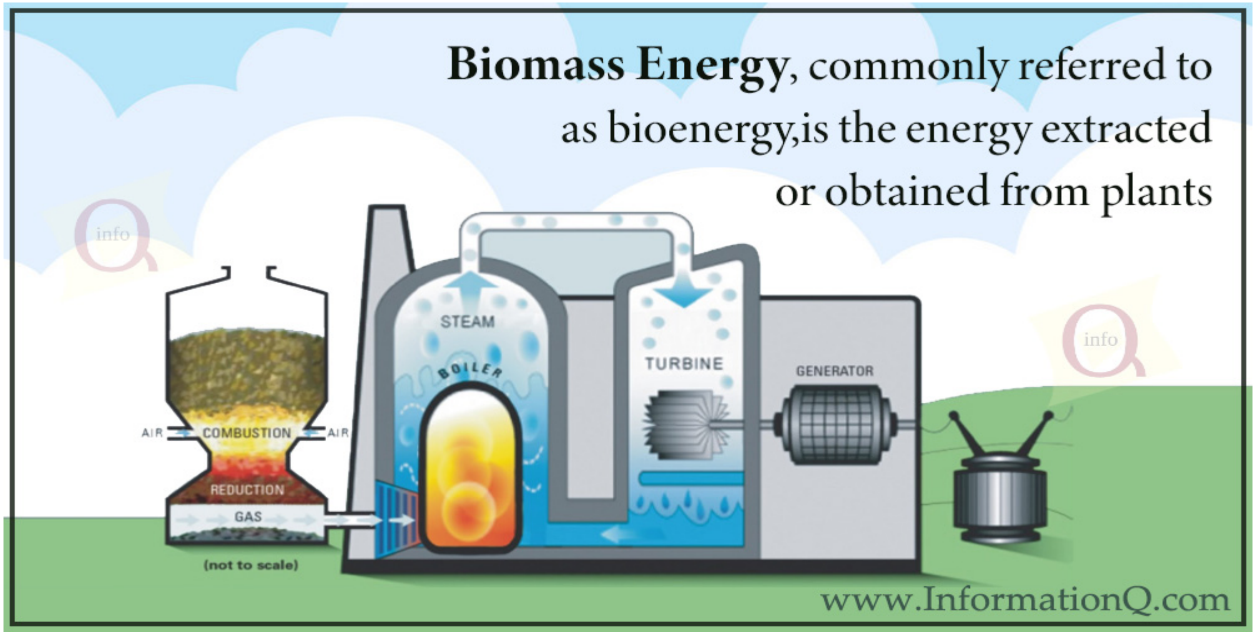

Fig. 1.3 Biomass Energy

1.2.4 GEOTHERMAL ENERGY

Geothermal energy, residing within Earth's crust, stems from both planetary formation and radioactive decay. Elevated temperature and pressure in the planet's core drive certain rocks to liquefy and the solid mantle to exhibit plastic behavior. Consequently, portions of the mantle convect upwards due to their lighter nature compared to surrounding rock. At the core-mantle boundary, temperatures can exceed a scorching 4000°C (7200°F).We can use this heat to make energy. Wells are drilled into hot areas and water is sent down. The water turns into steam, which can be used to turn turbines and create electricity. Geothermal energy can also directly heat buildings. It's clean and doesn't make pollution like coal or oil. This energy is always there, day and night. It's great for places near hot spots, like volcanoes, and can even be used in cold areas. Geothermal energy is like tapping into the Earth's warmth to make power for our homes and more.

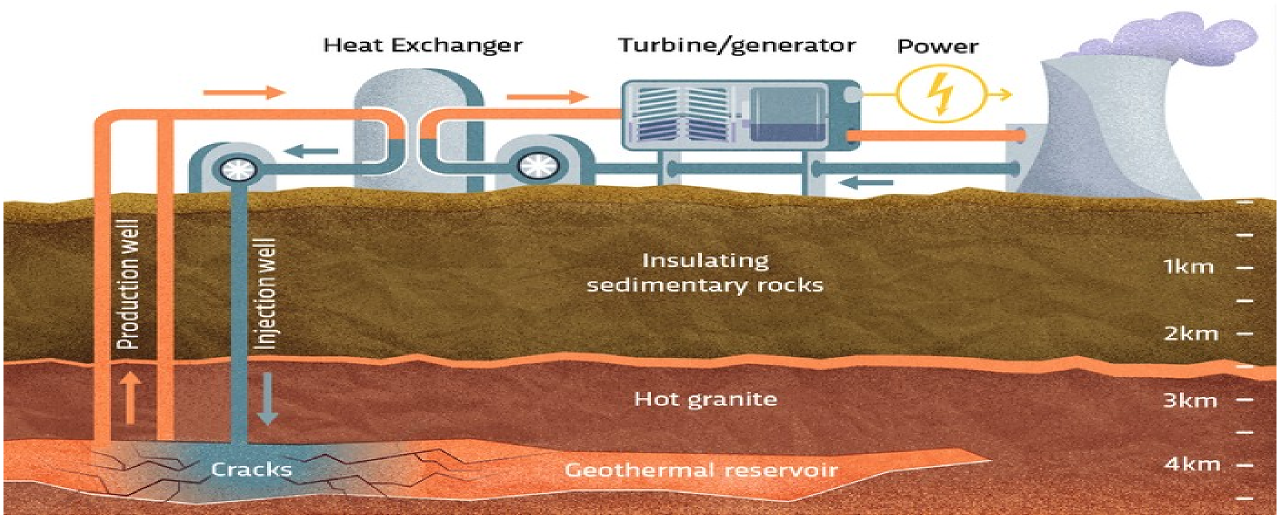

Fig. 1.4 Geothermal Energy

1.2.5 HYDROPOWER

Hydropower, derived from the Greek term "water," taps into the energy potential of falling or swift-flowing water to generate electricity or drive machinery. This entails converting the gravitational or kinetic energy of water sources into power. Serving as a sustainable energy avenue, hydropower predominantly fuels hydroelectric generation while also playing a role in pumped-storage hydroelectricity systems. Offering an environmentally favorable alternative to fossil fuels, it avoids direct carbon dioxide emissions and ensures a relatively stable power supply. Nevertheless, its adoption involves economic, social, and ecological considerations, demanding an ample supply of energetic water, like rivers or elevated lakes. Recognized by entities like the World Bank, hydropower is hailed as a low-carbon catalyst for economic advancement.

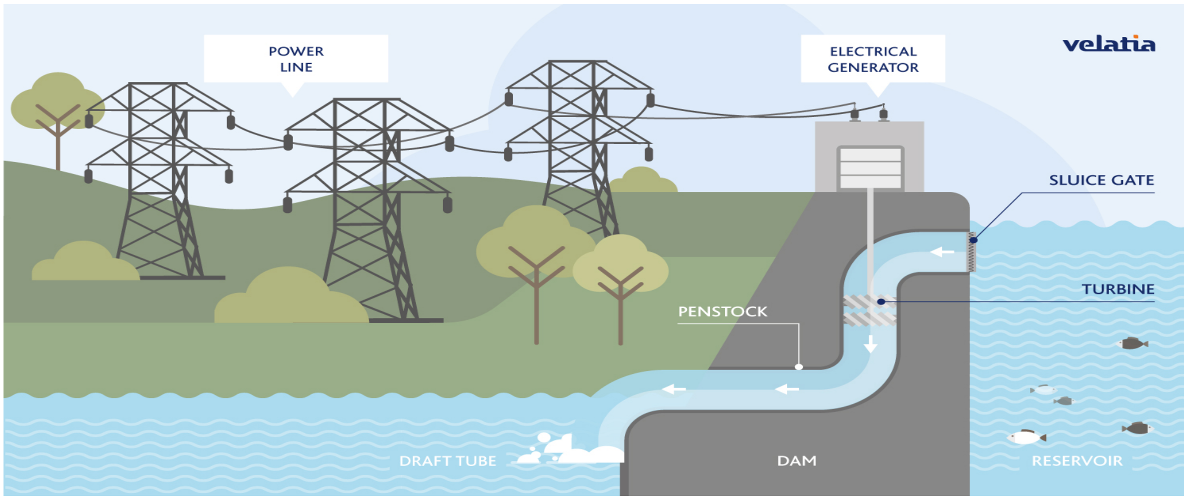

Fig.1.5 Hydropower

1.2.6 OCEAN ENERGY

Ocean energy, also known as marine energy, harnesses the power of the ocean's tides, waves, and currents to create useful energy. Tides rise and fall predictably due to the moon's pull, and waves are formed by the wind. Both of these can be turned into electricity using special devices. Ocean currents, caused by temperature differences and the Earth's rotation, can also be tapped for energy. Ocean energy is attractive because it's very consistent, with tides and waves following regular patterns. It's a clean source of power, not emitting pollutants like fossil fuels. However, setting up devices underwater can be challenging due to the harsh ocean environment, and the technology is still developing. Despite these challenges, ocean energy holds promise as a renewable energy source that can contribute to our energy needs while being friendly to the environment.

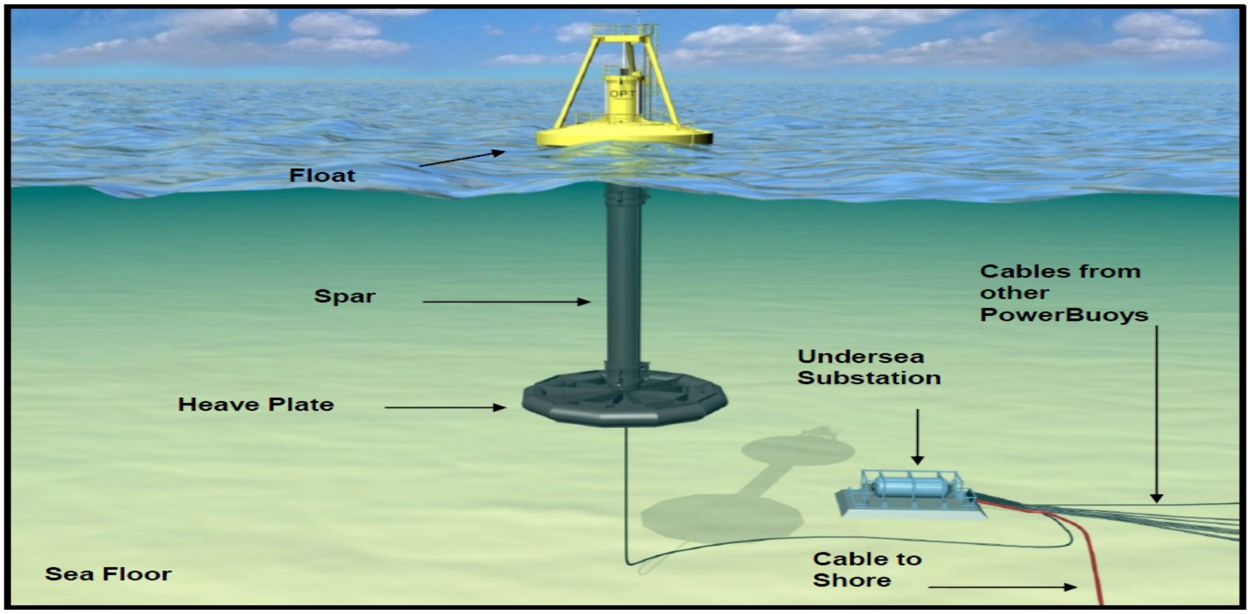

Fig 1.6 Ocean Energy

1.3 WHY WE NEED RENEWABLE ENERGY

We require renewable energy to combat climate change, reduce pollution, and ensure a sustainable future. Fossil fuels emit harmful greenhouse gases, causing environmental degradation and impacting human health. Renewable sources like solar, wind, and hydro offer clean alternatives, curbing carbon emissions and mitigating air and water pollution. They provide reliable, long-term energy solutions, reducing our dependence on finite resources and enhancing energy security. Moreover, renewable energy fosters innovation, job creation, and economic growth, while enabling access to power in remote and underserved regions. Embracing renewable is imperative for ecological balance, improved health, and the well-being of current and future generations.

Here are our top reasons why now is the perfect time to start using renewable energy-

1.3.1 BETTER FOR THE ENVIRONMENT

Fossil fuels are causing major problems in India too, releasing harmful gases that harm the air and contribute to issues like extreme weather and pollution. The impacts are serious, with cities like Delhi often facing hazardous levels of air quality. To address these challenges, India is also turning towards renewable energy, which is better for the environment and health. Many Indians suffer from health problems due to polluted air, and using cleaner energy sources like solar and wind power can improve this situation. India has abundant sunlight and wind, making it well-suited for renewable energy. The country has set ambitious goals to increase its renewable energy capacity, aiming to generate a significant portion of its electricity from renewable sources. By embracing renewable energy, India can tackle pollution, promote healthier living, and ensure a more sustainable energy future for its growing population.

1.3.2 FOSSILE FUELS ARE LIMITED

Fossil fuels, including coal, oil, and gas, are finite resources formed from ancient plant and animal remains over millions of years. Their supply is limited, and they are termed "non-renewable." These hydrocarbons—combinations of carbon and hydrogen—play a crucial role in daily life. They're central to energy production, providing heat, electricity, and fuel for engines. When burned in the presence of oxygen, the bonds between carbon and hydrogen atoms release stored energy, transforming it into heat and producing carbon dioxide (CO_2). As non-renewable resources, fossil fuels are exhaustible and will eventually be depleted, underscoring the need for transitioning to sustainable, renewable energy sources.

- **Coal**

Before dinosaurs roamed the Earth, large plants and ferns lived in swampy forests. When these plants died, their remains piled up in swampy areas. As time passed, layers of sediment and water covered these remains, and the pressure and heat from the layers above caused changes to happen. This process turned the plant remains into coal through chemical and physical changes. The lack of oxygen during this process led to the decay of the plants and ferns, transforming them into coal over a very long time.

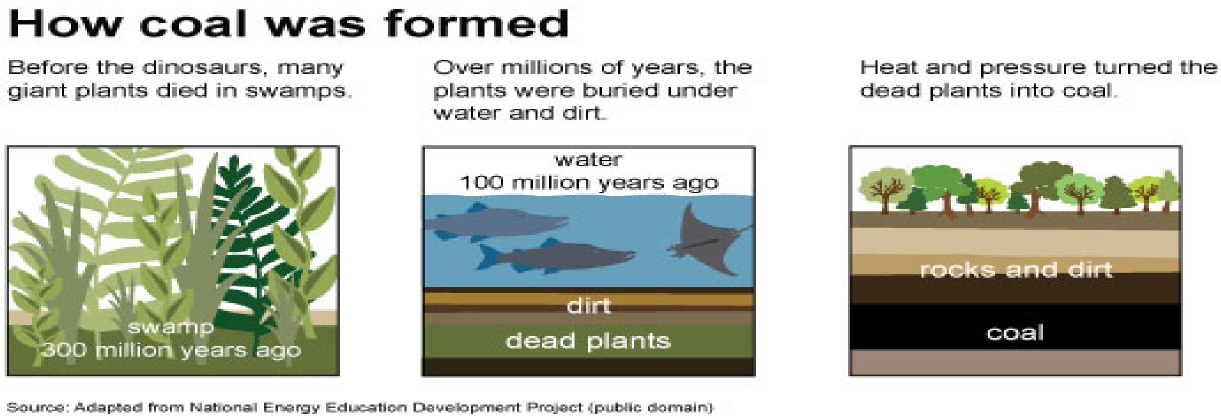

Fig. 1.7 Coal Formation

- **Oil and Gas**

The oil and gas we use today come from tiny marine creatures that lived a very long time ago. When these creatures died, their bodies sank to the ocean floor and got covered by layers of sand and mud. In places where the water didn't move much, like calm lakes or still seas, their bodies broke down without oxygen. Over time, more layers built up, pushing down and heating the sediment. This mix of pressure and heat turned the decaying material into oil and gas. Sometimes, these oil and gas deposits come up to the surface, seeping into the ground or water. Other times, they get trapped under rocks that won't let them through, so we have to drill to get them out. Natural gas, the main part of this, is mostly methane (CH4), but it can also have other gases like butane and propane. This natural process took many, many years and is how we get these important sources of energy that we use today.

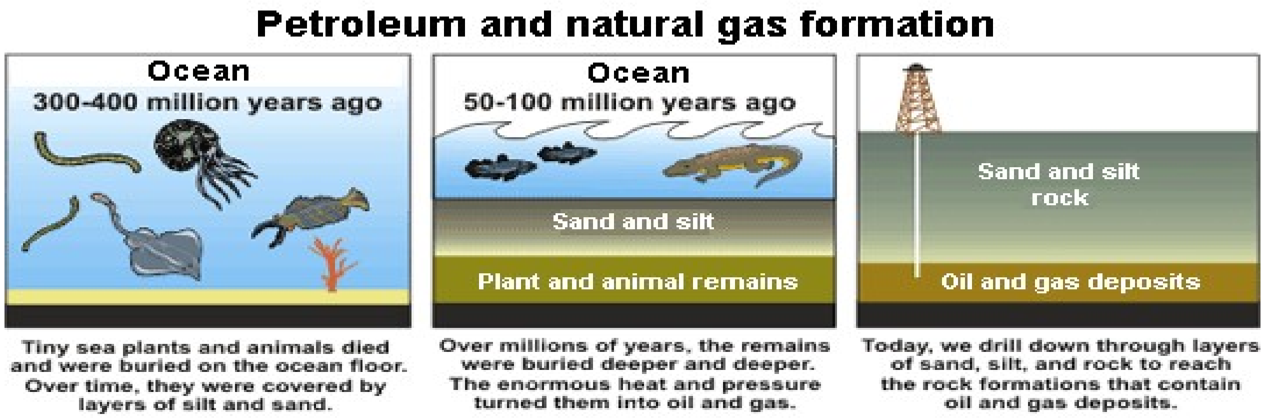

Fig. 1.8 Oil and Gas Formation

- **Peat**

Peat is like an early form of coal that turns into coal over a very long time. It comes from plants and sometimes trees that decay in wet places. These dead plants pile up and break down for many, many years. This happens a lot in areas where water can't drain well, often because of leftover stuff from old glaciers. These leftover things, like eskers and moraines, were left behind when ice melted a long time ago. This happens in places like the middle of Ireland. These old glacier leftovers stop water from draining properly. With lots of rain and not much air, plants keep growing and dying, layer after layer. This creates peat. It's interesting how nature and the Earth's history work together to shape things over a very long time.

1.3.3 Environmental Pollution:

Fossil fuels are used for energy by burning them in big power plants with air. This burning makes heat, which heats up water to become steam. This steam pushes a spinning thing called a turbine. The spinning of the turbine makes mechanical energy turn into electricity. But burning fossil fuels, like oil and gas, is bad for the environment. When they burn, they make a gas called carbon dioxide (CO2) which makes the Earth warmer. This happens when we burn natural gas too. This whole process shows that we need cleaner and better ways to make energy, like using renewable sources, to stop harming the environment.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

• **Air Pollution**: Burning fossil fuels releases harmful pollutants like sulfur dioxide, nitrogen oxides, carbon monoxide, and mercury. These pollutants can lead to acid rain, damage crops and forests, and harm wildlife. Air pollution also threatens human health, causing respiratory issues and other illnesses.

• **Water Pollution**: Fossil fuel activities, including things like oil spills and fracking, can make water sources dirty. For example, when fracking happens, a lot of water mixed with harmful chemicals is used. The water that comes back up can have dangerous things like lead, arsenic, and mercury in it. This can make the water underground and the water we drink not safe.

• **Plastic Pollution**: Over 99% of plastics are derived from fossil fuels. The global plastic waste problem is immense, with millions of tons ending up in oceans, endangering wildlife and polluting the food chain. Additionally, plastic production emits significant greenhouse gases, impacting the climate.

• **Oil Spills**: Getting fossil fuels out of the ground, moving them around, and making them usable can lead to big accidents where a lot of oil spills into the environment. These spills are really bad for nature, communities, and animals. For example, the BP Deepwater Horizon spill in 2010 let out a huge amount of oil into the Gulf of Mexico. This caused a lot of harm to the environment and cost a lot of money to clean up.

Fig. 1.9 Environmental Pollution

1.3.4 PUBLIC HEALTH

The burning of fossil fuels creates harmful air pollution that seriously affects people's health. Illnesses like asthma, cancer, heart problems, and even premature death are connected to this pollution. In India, gasoline additives containing substances like benzene, toluene, ethylbenzene, and xylene make dangerous tiny particles and cancer-causing chemicals. On a global level, about one in every five deaths is linked to pollution from fossil fuels. In India, the situation is also concerning, with fossil fuel pollution causing health issues.

For instance, in 2019, it was estimated that around 1.67 million deaths in India were due to air pollution, a significant portion of which is linked to fossil fuel pollution. In cities like Delhi, the air quality often reaches hazardous levels, affecting people's well-being. The health costs of fossil fuel-related pollution are substantial, including hospitalizations, medical treatments, and lost productivity.

India needs to focus on transitioning to cleaner and more sustainable energy sources to address this public health crisis. By reducing reliance on fossil fuels and promoting renewable energy alternatives, the country can improve air quality, protect public health, and build a more sustainable future.

1.4 WHAT IS REFRIGERATION SYSTEM

Refrigeration encompasses various methods of cooling that lower or sustain temperatures below the surrounding environment, removing the extracted heat to a higher-temperature location. It's an artificial cooling technique created by humans. This process involves transferring heat energy from a colder medium to a warmer one. An air conditioning system, for instance, incorporates components like a condenser, a compressor, expansion devices, and an evaporator. The refrigerant flows through these components, undergoing stages of compression, expansion, and evaporation. A control unit detects operating parameters and determines optimal settings for components like the expansion device based on stored values, facilitating efficient cooling and temperature regulation.

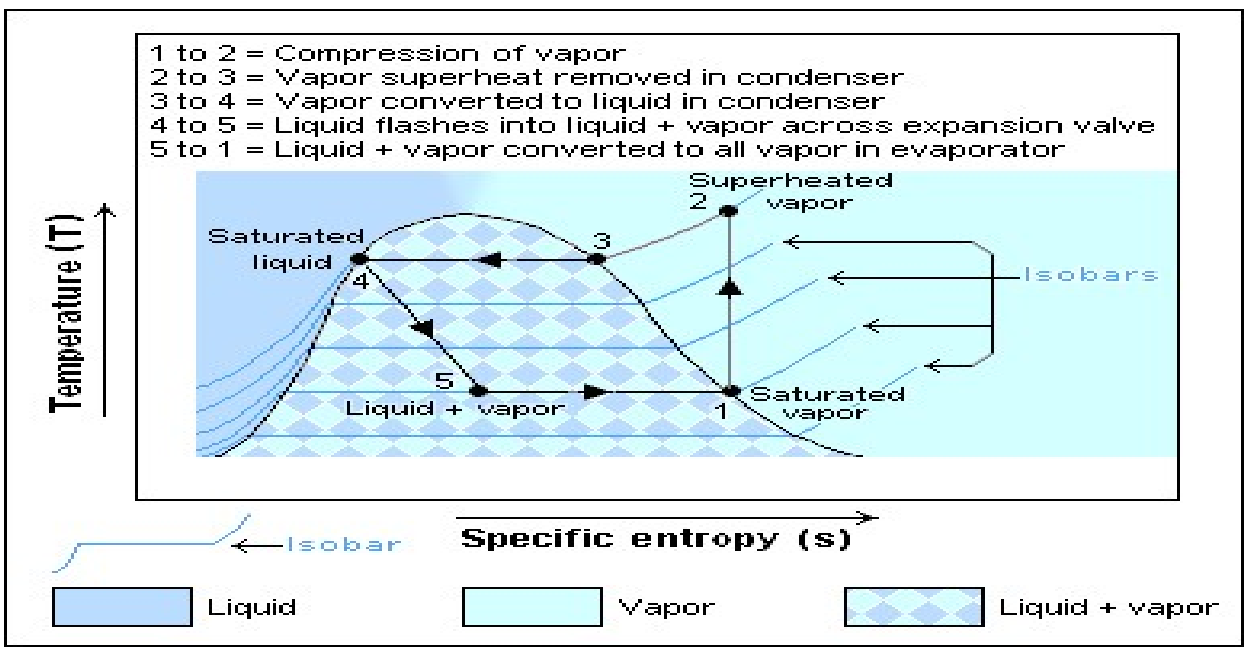

Fig. 1.10 T-S Graph of Refrigeration system

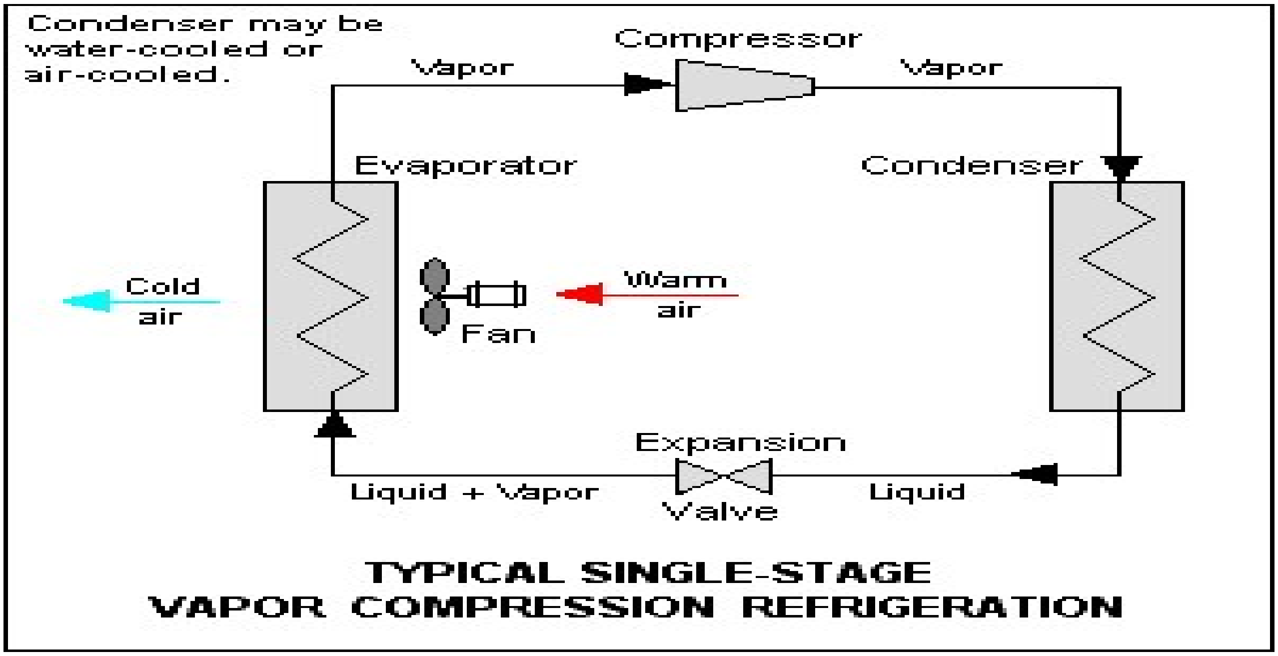

Fig. 1.11 Basic component of Refrigeration system

1.5 NATURAL REFRIGERANT

Refrigeration technology has significantly elevated the human standard of living, with inventions like refrigerators and air conditioners becoming essential for comfortable living. However, from its inception, the refrigeration industry has grappled with safety and environmental concerns linked to refrigerants. Despite research efforts, the industry remains a notable contributor to environmental degradation.

Early struggles with natural refrigerants' issues like flammability paved the way for the discovery of CFCs and HCFCs, which gained popularity due to their exceptional properties and safety. However, in 1974, it became evident that these compounds were depleting the ozone layer, allowing harmful UV rays to penetrate Earth's atmosphere. The Montreal Protocol of 1987 initiated the phase-out of CFCs and HCFCs.

As the industry transitioned from CFCs to HCFCs and subsequently to HFCs, global warming emerged as a new concern. The higher global warming potential (GWP) of HFCs necessitated the search for eco-friendly, energy-efficient alternatives. This quest led researchers back to natural hydrocarbons like isobutane (R600a).

Natural refrigerants, derived from the environment, include substances like water, ammonia, carbon dioxide, air, and hydrocarbons. While some have been in use for decades, their application varies. These natural options address both environmental and energy efficiency concerns, signaling a return to eco-friendly solutions that align with the principles of sustainability.

ODP and GWP of Select Synthetic and Natural Refrigerants

Classification	Refrigerant	Ozone Depletion	Global Warming Potential
CFC	R-12	1	10900
	R-502	.33	4657
HCFC	R-22	.055	
	R-123	.66	

Table No.1.1 ODP and GWP of Select Synthetic and Natural Refrigerants

1.5.1 Hydrocarbons as refrigerants

Hydrocarbons find practical application in refrigeration, offering effective cooling capabilities while being abundant and energy-efficient. Their use as refrigerants is supported by their significant energy efficiency, which can be up to 50% higher than synthetic alternatives. Moreover, hydrocarbons align well with environmental considerations, as they occur naturally and have a low impact on the global warming potential (GWP).

In refrigeration history, hydrocarbons primarily found utility in industrial cooling and refrigeration. However, with the ongoing shift towards natural refrigerants, their application is expanding across various refrigeration sectors. They are gaining traction as a favored option, especially in European countries, due to their eco-friendly nature and efficiency. This trend underscores the growing recognition of hydrocarbons' potential to strike a balance between effective cooling and responsible environmental stewardship.

Hydrocarbons used as refrigerants include:

- Methane (CH_4) [R-50]
- Ethane (CH_3CH_3) [R-170]
- Propane ($CH_3CH_2CH_3$) [R-290]
- Ethylene (CH_2CH_2) [R-1150]
- n-Butane ($CH_3CH_2CH_2CH_3$) [R-600]
- Isobutane ($CH(CH_3)_3$) [R-600a]
- Propylene (CH_3CHCH_2) [R-1270]
- Pentane ($CH_3CH_2CH_2CH_2CH_3$) [R-601]
- Isopentane ($CH(CH_3)_2CH_2CH_3$) [R-601a]

1.5.2 Isobutene

Isobutane, also referred to as i-butane, 2-methylpropane, or methylpropane, has the chemical formula $HC(CH_3)_3$. It represents an isomeric form of butane. This colorless and odorless gas stands as the simplest alkane featuring a tertiary carbon atom. Isobutane plays a vital role in the petrochemical sector, often serving as a precursor molecule. Notably, it finds application in processes like the synthesis of isooctane, showcasing its significance in various industrial applications.

Names
2-Methylpropane
Isobutane,R600a

Table No.1.2 Isobutane IUPAC Name

Properties					
Chemical Formula	C_4H_{10}	Melting point	−159.42 °C (−254.96 °F; 113.73 K)	Critical Temperature	135°C
Molar Mass	58.124 g/mol	Boiling Point	−11.7 °C (10.9 °F; 261.4 K)	Critical Pressure	3.65 MPa
Odor	odorless	Density	2.51 kg/m^3(at 15 °C, 100 kPa)	Solubility in water	Insoluble
Assigned colour code	Colourless gass	Vapour pressure	204.8 KPa (at 21 °C (294 K; 70 °F))	Latent heat of evaporation	362.6 KJ/Kg at atm pressure

Table No.1.3 Isobutene Properties

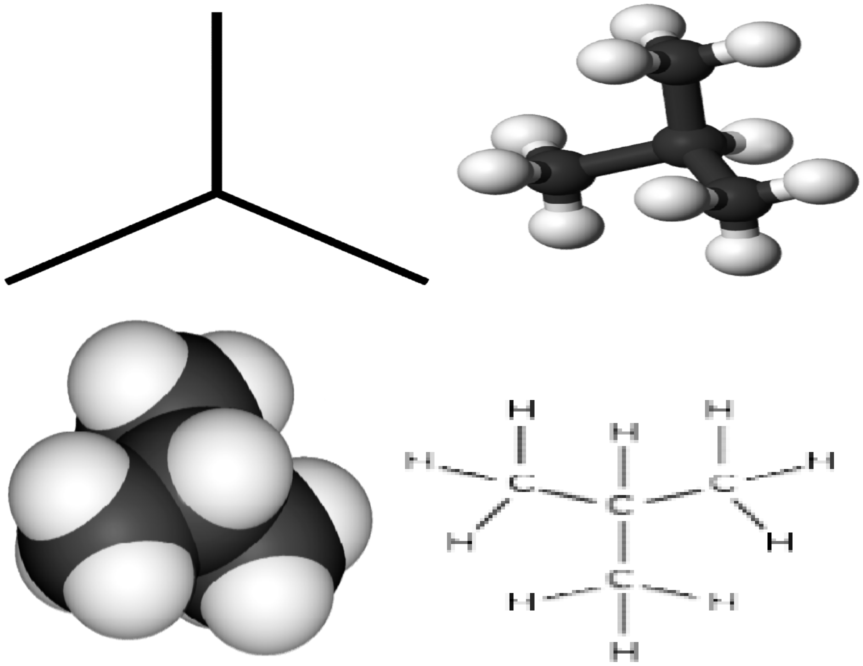

Fig.1.12 Isobutene

1.6 WHAT IS SOLAR THERMAL ENERGY SYSTEM

A solar thermal energy system is a technology that uses the sun's heat to produce heat or electricity for diverse applications. Unlike photovoltaic systems that directly convert sunlight into electricity, solar thermal systems capture and utilize solar heat.

These systems comprise key components:

1. **Solar Collectors**: Devices that capture sunlight and convert it into heat. Flat-plate collectors and concentrating collectors are common types. Flat-plate collectors serve residential and commercial water heating, while concentrating collectors are used in larger applications like power generation.
2. **Heat Transfer Fluid**: This fluid absorbs heat from sunlight as it circulates through collector. Then it transfers this heat to storage or a heat exchanger.

3. **Heat Storage**: Often includes systems to store excess heat for later use, even when sunlight isn't available. Storage mediums include water tanks, molten salt tanks, and heat-storing materials.
4. **Heat Exchangers**: Transfer heat from the fluid to the medium requiring heating. For instance, in residential water heating, a heat exchanger transfers heat from the fluid to water.
5. **Applications**: Solar thermal systems find applications in water and space heating, pool heating, and industrial processes. Large power plants also use them to generate electricity by converting collected heat into steam to drive turbines.

Advantages include renewable energy use, low operating costs, reduced emissions, and energy independence. Yet, challenges include upfront costs and reliance on sunlight availability. Factors like shading, dust, and maintenance can impact efficiency.

In essence, solar thermal systems offer a sustainable solution for various heating and energy needs by harnessing the sun's heat, promoting a cleaner energy future.

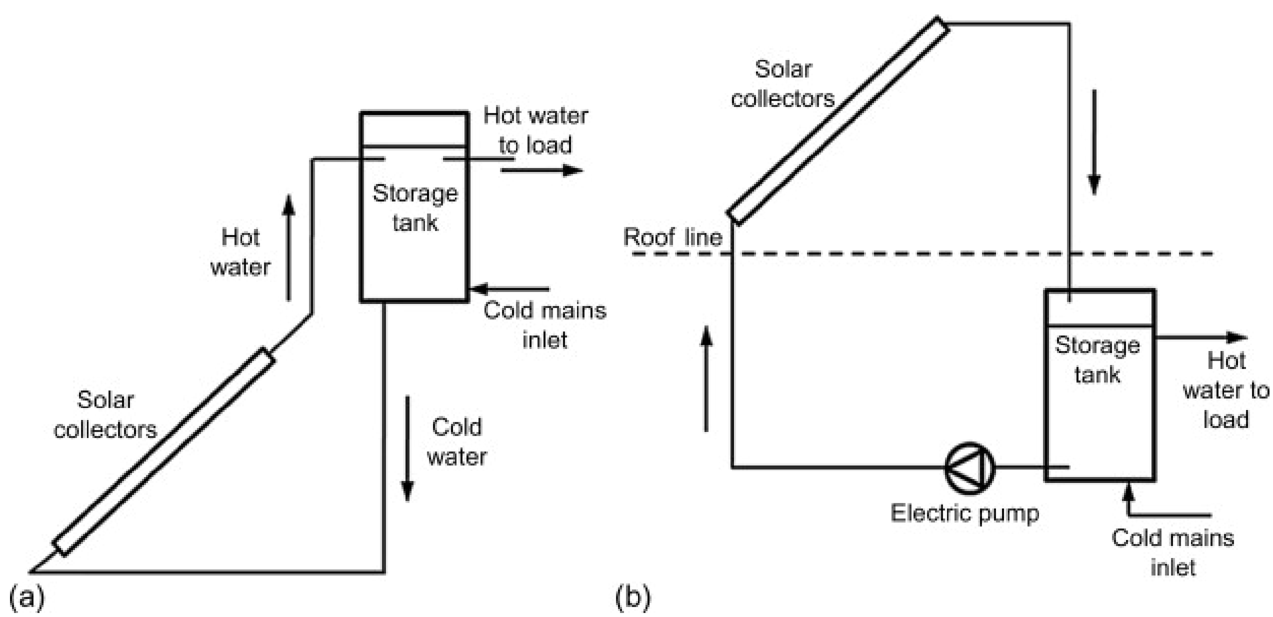

Fig.1.13 Solar Thermal Energy System

1.7 RENEWABLE HYBRID ENERGY SYSTEM RECENT TRENDS IN INDIA

In recent years, India has made significant steps in the adoption of renewable hybrid energy systems, driven by the country's commitment to sustainable development and reducing its carbon footprint. As of 2021, India's total installed renewable energy capacity has reached around 93.06 GW, with solar and wind energy being the dominant contributors. The National Institute of Solar Energy (NISE) reports that solar energy accounts for approximately 44.57 GW, while wind energy contributes around 40.32 GW to the total capacity.

One of the key drivers behind this trend is the government's aggressive renewable energy targets. India aims to achieve 175 GW of renewable energy capacity by 2022, including 100 GW of solar energy and 60 GW of wind energy. These targets are part of the broader plan to increase the share of non-fossil fuel-based capacity to 40% of the total capacity by 2030.

Solar energy, in particular, has witnessed a remarkable surge in recent years. The country's solar capacity has grown at an impressive compound annual growth rate (CAGR) of over 50% between 2015 and 2020. The Jawaharlal Nehru National Solar Mission (JNNSM) has been instrumental in driving this growth, fostering the development of utility-scale solar projects, rooftop solar installations, and solar parks.

Wind energy also continues to play a significant role in India's renewable energy landscape. The country has consistently ranked among the top wind energy producers globally. With a total wind energy potential estimated at over 300 GW, India's installed wind capacity has reached around 40.32 GW, showcasing its substantial utilization of this renewable source.

Certainly, here's an overview of the development of renewable hybrid energy systems in different states of India, along with relevant data:

1. **Gujarat:** Gujarat has been a pioneer in renewable energy adoption, particularly solar power. The state has harnessed its solar potential through large-scale solar parks and rooftop installations. As of 2021, Gujarat boasts an installed solar capacity of approximately 3.4 GW, contributing significantly to India's solar capacity. The state's

solar parks, such as the Charanka Solar Park, have attracted substantial investments and propelled its solar growth.

2. **Karnataka:** Karnataka is another frontrunner in the renewable energy sector. The state has a diverse renewable energy portfolio, with a strong focus on wind and solar power. Karnataka's installed solar capacity has crossed the 7 GW mark, making it one of the leading solar states in the country. The state's proactive policies and incentives have led to widespread adoption of solar rooftop systems.

3. **Tamil Nadu:** Tamil Nadu has been a long-standing leader in wind energy generation. The state's abundant wind resources have enabled it to achieve a substantial wind capacity of around 9.5 GW. Additionally, Tamil Nadu has made significant strides in solar energy, with an installed solar capacity of over 3 GW. The state's innovative policies have attracted investments in both wind and solar sectors.

4. **Rajasthan:** Rajasthan's geographical advantage of ample sunlight has positioned it as a prime destination for solar energy projects. The state houses some of India's largest solar parks, contributing to its installed solar capacity of around 3.5 GW. Rajasthan's initiatives in hybrid projects, combining solar and wind energy, showcase its commitment to renewable hybrid systems.

5. **Andhra Pradesh:** Andhra Pradesh has demonstrated noteworthy growth in both solar and wind energy. The state's installed solar capacity is around 2.5 GW, and its wind capacity stands at approximately 4.1 GW. The establishment of dedicated solar and wind parks has played a crucial role in promoting renewable energy deployment.

6. **Maharashtra:** Maharashtra has a significant renewable energy presence, driven by a mix of solar, wind, and small hydro projects. The state's installed solar capacity is around 2.9 GW, while its wind capacity exceeds 5 GW. Maharashtra's proactive approach towards clean energy policies has fostered growth in both utility-scale and distributed renewable installations.

7. **Telangana:** Telangana has rapidly emerged as a renewable energy hub, with a particular focus on solar power. The state's installed solar capacity has crossed 4.5 GW, indicating substantial growth. Telangana's strategic solar policies and implementation of solar parks have propelled its solar energy sector.

8. **Madhya Pradesh:** Madhya Pradesh's renewable energy sector has been gaining momentum. The state's installed solar capacity is around 2.3 GW, and its wind capacity stands at approximately 1.3 GW. Madhya Pradesh's efforts in solar energy auctions and attractive policies have attracted investments in the renewable sector.

These states' efforts collectively contribute to India's achievement of a cleaner and more sustainable energy landscape. The data underscores the substantial progress made in renewable energy capacity installation across different states, promoting the adoption of renewable hybrid energy systems and aiding the nation's journey towards a greener future.

1.8 AIM AND OBJECTIVE OF THE THESIS

Hybrid renewable system is one of the most acceptable system towards the green energy future. Although it is not emitted any pollutant gases except bio gas, it is most desirable to the people and due to hybrid system there is also cost efficient for same power generation. The major objectives of the present work are given below in brief.

This project **is** Hybrid Refrigeration system (HRS) which is a combination of solar water heating system (SWHS) and the refrigeration system with natural refrigerant. We are trying to reduce the compressor work with help of super heating. In this project we are trying to increase the pressure and temperature of the refrigerant in the inlet of the compressor with help of the SWHS. This hybrid system gives a good reduction in compressor work that reason it takes less electricity than a traditional refrigeration system for cooling items in refrigerator. Our main goal is to make a hybrid sustainable system which is energy efficient to the society.

1.9 OVERVIEW OF THESIS

Now a day renewable energy is getting more importance than fossil fuels. Renewable energy is more sustainable and green energy. So, in this project we are trying to make a hybrid system which a combination of solar water heating system and a vapor compression refrigeration system with natural refrigerant. In this project we used natural refrigerant (isobutene) which is eco friendly. Our main focus is to reduce the compressor work and increase the c.o.p of the hybrid system. At first we are making a design of solar water heating system in matlab in a standard temperature and pressure, after that we make a design of refrigeration system in matlab and then we combine the two system and make a hybrid refrigeration system where we use natural refrigerant isobutene as a refrigerant. In this project our main focus to use the pressure and temperature of the SWHS and it is used to increase the pressure and temperature of the inlet of the compressor which helps to reduce the compressor work and it will help to increase the c.o.p of the HRS. We also compare c.o.p of the HRS with normal refrigeration system (NRS) at different temperature and pressure .Understand the p-h curve of the HRS and NRS. Also gain knowledge of natural refrigerant and their properties. Calculate the compressor work of HRS and NRS. We also consider different parameters for a optimal design, further design and calculation is described next chapters of this project.

1.10 CONCLUSION

In this chapter we discussed renewable energy sources, understand the requirement of renewable energy system, effects of fossil fuels and its limitation and also discussed the trend of hybrid system in India .Trying to execute aim and objectives of this thesis and also a short overview of this thesis. Further we understand the design of HRS with natural refrigerant in Matlab Simulation software and the various types of calculation parameters are discussed later. In the next chapter, review of earlier work, gap of knowledge and probable solution is described thoroughly.

CHAPTER 2

REVIEW OF EARLIER WORK

2.1 INTRODUCTION

We discussed different types of renewable energy sources earlier. Renewable energy sources are used to produce electricity with very less impact on environment. It is important to understand that renewable energy sources are not producing any harmful gases, Co2, NOx which is responsible for global warming. We all know that renewable energy is a green energy. So in this field, hybrid energy system is very important for energy producing.

In this chapter a literature review is a search and evaluation of the available literature in hybrid renewable energy system a literature has four main objectives.

1. It surveys the literature on hybrid renewable energy system.

2. It synthesizes the information in that literature into a summary.

3. It critically analyzes the information gathered by identifying gaps in current knowledge by showing limitation of theories and points of view and by formulating the areas for further research and reviewing areas of controversy.

4. It presents the literature in an organized way.

Literature reviews have been given in depth knowledge of HRS with natural refrigerant models and have also been understudied where your own research fits into and adds to an existing body of agreed knowledge.

2.2 LITERATURE SURVEY

I. Dauta, M. Adzriea, M. Irwantoa, P. Ibrahima, M. Fitraa have investigate on solar power air conditioning system to minimize the cost of a day to day airconditioning system. The demand for air conditioning is on the rise due to climate change and global warming. However, relying on conventional electric air conditioning powered by fossil fuels worsens greenhouse gas emissions and exacerbates global warming, leading to even higher air conditioning demand. In cities with subtropical climates, air conditioning is standard, but it can consume up to half of a building's electricity.

Air conditioning refers to the process of controlling temperature, humidity, air purification, and air distribution to meet the needs of a space. It involves removing heat, usually requiring energy from sources like gas and electricity. As gas and electricity costs increase, solar energy becomes an attractive option once the system is set up. Solar energy is particularly well-suited for installation in subtropical regions as a renewable energy source.

Absorption cooling is a commonly preferred type of thermally driven technology for cooling using solar energy. This system offers simplicity in capacity control, easier implementation, high reliability, quiet operation, durability, and low maintenance costs . However, this project focuses on enhancing a conventional air conditioner to operate using electricity generated by a solar photovoltaic (PV) system. Using solar energy to power air conditioning is a practical way to replace traditional electricity sources.

Research and testing have been conducted to understand the design and operation of an air conditioning system combined with a PV solar system. The goal is to assess the feasibility of using solar energy for air conditioning. This paper aims to design and create a direct current air conditioning system. It outlines the system's components, characteristics, advantages, and limitations. The system's real-world performance will be examined from an operational perspective and its potential for commercial applications.

In conclusion, the increasing demand for air conditioning in the face of climate change necessitates cleaner energy sources. Relying on conventional fossil fuel-generated electricity exacerbates the problem. Utilizing solar energy for air conditioning offers a practical solution to reduce emissions. This paper focuses on adapting and enhancing traditional air conditioning systems to run on solar-generated electricity, exploring its feasibility and benefits.

Qudama Al-Yasiri , Márta Szabó , Müslüm Arıcı have study on A review on solar-powered cooling and air-conditioning systems for building applications. To improve the air conditioning system, we use solar thermal energy in refrigeration cooling system and reduce the electricity in our homes, colleges day to day life. Solar thermal energy is commonly used to provide the necessary temperature for Solar Cooling and Air Conditioning Systems (SCACSs).

These systems are grouped into open, closed, and thermo-mechanical cycles. Open cycles directly process indoor air by adjusting temperature and humidity. In closed cycles, chilled water circulates in closed loops. Thermo-mechanical cycles use thermal energy, not mechanical, to create cooling effects via devices like ejector systems.

Ejector Cooling Systems (ECS) are innovative cooling devices utilizing solar thermal energy. ECS features inlet ports for primary and secondary flows, along with a nozzle, suction chamber, mixing chamber, and diffuser. It accelerates low-pressure secondary flow by mixing with the primary and releasing through an outlet with intermediate pressure. ECS replaces the compressor in Vapour Compression Refrigeration (VCR) systems in the Ejector Cooling Cycle (ECC).

This article primarily focuses on widely used solar cooling systems: Solar Absorption Systems (SABSs), Solar Adsorption Systems (SADSs), and Solar Desiccant Systems (SDSs). Solar collectors extract thermal energy from sunlight, with varied temperature ranges depending on the heat extraction method. While Flat Plate Solar Collectors (FPSCs) are common for SCACSs, they find various applications such as solar heating, domestic hot water, solar drying, solar desalination, and solar cooking. Parabolic Trough Solar Collectors (PTSCs) are extensively studied for solar cooling, often outperforming FPSCs.

Solar thermal collectors generally have thermal efficiencies ranging from 0.06 to 0.64. They've undergone significant development, utilizing advanced techniques and enhancers to improve efficiency and extend temperature availability. The main SCACS types - solar absorption, solar adsorption, and solar desiccant systems - are explored in detail in this article. These systems play a crucial role in harnessing solar energy for cooling and air conditioning, addressing environmental concerns and energy efficiency.

I Péter Szabó1, S Csikós1 and J Sárosi1 have study on Developing a MATLAB model for flat solar collectors to understand how much heat energy coming from the sun, is really converted in the form of water thermal energy in solar collectors. To conduct tests on our solar collectors and other collector-related research, we developed a specialized measuring equipment. This equipment is capable of measuring the efficiency of the collectors as a function of specific solar irradiation and the temperature difference between the collector and the surrounding ambient air.

In our system, we maintain control over the temperature difference between the collector and the ambient air using a fan coil. This device transfers heat from the collectors to the surrounding air. This setup enables us to adjust the fluid's temperature at the collector intake, allowing us to simulate transient effects. Throughout these tests, we used data loggers to record values at 5-second intervals.

Calculating the instantaneous efficiency of a solar collector is a critical aspect of this process. Using the data collected during measurements, we developed a MATLAB model for the solar collectors under analysis. With this model, we can effectively predict the efficiency function of the collector. This enables us to pre-calculate the efficiency function while designing a flat solar collector.

By utilizing this measurement equipment and the developed MATLAB model, we enhance our understanding of solar collectors' efficiency and behavior. This approach helps us optimize collector designs and make informed decisions for better energy capture and utilization.

The efficiency of a solar collector is influenced by various factors. For a specific type of collector, these factors remain constant. According to established practices in scientific research institutes, the efficiency function of the analyzed solar collector is determined by two independent variables, which are:

– intensity of solar irradiation (G, Wm-2),

– temperature difference between the collector and the ambient air (°C).

Under real operating conditions, a solar collector or absorber experiences three types of heat losses: radiative, conductive, and convective. These losses are initially zero when the fluid is at the ambient temperature (t = 0), and they increase over time as the liquid's temperature rises.

Typical heat losses of a flat solar collector illustrates how the efficiency of the collector is impacted by various factors. It highlights that:

– light transmission and thermal insulation capability of the cover,

– the heat absorbing ability of the absorber surface,

– the geometrical design and connection of the absorber surface and the pipeline,

– the thermal insulation of the collector house.

Based on the above losses, the thermal network model of the flat solar collector can be created. Calculating the instant efficiency of a solar collector is complex. Using measurements, a MATLAB model for the solar collectors is created. This model helps design flat solar collectors, predicting their efficiency in advance.

Y. Tian a, C.Y. Zhao have research on a solar collectors and thermal energy storage in solar thermal applications. We are trying to know the solar collectors are working, their performance, efficiency and how its react with the solar irradiation. The issue of CO_2-induced global warming has become urgent and requires action. Using renewable energy efficiently, particularly solar energy, is seen as a promising solution to combat global warming and achieve sustainable development. The Sun radiates an immense amount of energy: 174 petawatts (PW) at the upper atmosphere of Earth, where 1 PW equals 10^15 watts . This energy is attenuated twice, once by the atmosphere (6% through reflection and 16% through absorption) and again by clouds (20% through reflection and 3% through absorption). About 51% (89 PW) of the incoming solar radiation ultimately reaches the land and oceans. Despite the attenuation, the total solar energy available on Earth remains substantial. However, due to its low density and intermittent nature, efficient collection and storage are essential.

Solar thermal applications involve two key subsystems: solar collectors and thermal energy storage components. Solar collectors need excellent optical performance to absorb as much heat as possible . On the other hand, thermal storage systems require high storage density (compact volume and cost-efficiency), efficient heat transfer (quick heat absorption and release), and long-term durability .

In 2004, Kalogirou reviewed various common solar thermal collectors, providing thermal analyses and practical applications. However, technological advancements have occurred since then. Newer collector types, like Photovoltaic-Thermal (PVT) collectors, were not included in that review. This paper describes these recent technologies. While much of the literature on thermal energy storage has focused on low-temperature applications, only a few papers address high-temperature thermal energy storage.

For instance, Kenisarin reviewed potential phase change materials (PCMs) used from 120°C to 1000°C, detailing their thermal properties. Gil et al. reviewed high-temperature thermal storage systems, particularly for power generation, and outlined desirable materials and thermal models.

In conclusion, solar energy offers a promising solution to counter global warming. Despite attenuation, the available solar energy remains significant. Solar collectors and thermal energy storage are vital components of solar thermal systems. Technological advancements have brought new collector types, while thermal energy storage reviews have largely focused on low temperatures.Addressing high-temperature applications and utilizing innovative technologies are crucial for a sustainable energy future. Updates of the latest developments in high-temperature thermal storage technologies are given in the present paper. The text examines different thermal energy storage systems, including sensible heat storage, latent heat storage, chemical storage, and cascaded storage. These systems are looked at in terms of how they are designed, the materials used, and ways to improve heat transfer. Lastly, the text also provides an overview of current and upcoming solar power stations

Ahmed Al-Manea , Raed Al-Rbaihat , Hakim.T. Kadhim , Ali Alahmer , Talal Yusaf , Karim Egab have study on Experimental and numerical study to develop TRANSYS model for an active flat plate solar collector with an internally serpentine tube receiver.
This research focuses on flat plate solar collectors, commonly used to save energy in both homes and industries. The study involved creating and testing an active version of this collector in Al-Samawa city, Iraq, where the weather was around 39°C with strong sunlight at 840 watts per square meter. Unlike the traditional design with multiple tubes, they used a single tube that had a serpentine shape and covered it with plastic. This tube was made of smooth copper, measuring 1000 mm in length.
To understand its performance, they built a computer model of the collector and compared it to real-world tests. During these tests, they closely monitored the temperature and the speed of water flowing through the collector. The water's temperature at the collector's entry remained quite steady at 37.7°C, while the flow rate stayed constant at 0.75 liters per minute. The water that left the collector was noticeably warmer, varying from 52 to 61°C, with an average temperature of 58°C. In terms of efficiency, the collector performed well, ranging from 45% to 67% efficiency, with an average of 58%.
Remarkably, the computer simulation closely matched the real test results, with only a slight difference of around 1% between the two sets of data. This indicates the accuracy of their model and the potential effectiveness of the collector in real-world applications.

Mustafa Ozsipahi, Haluk Anil Kose , Husnu Kerpicci , Hasan Gunes have study on Experimental study of R290/R600a mixtures in vapor compression refrigeration system to understand the behavior of the refrigerants. This paper presents an experimental study focused on assessing the impact of R290/R600a refrigerant mixtures on the performance of variable speed hermetic compressors commonly used in household refrigeration systems. To conduct this research, a small-capacity compressor test stand was established, and the behavior of four distinct compositions of R290/R600a mixtures was investigated. The proportion of R290 in these mixtures was varied between 40% and 70% by mass weight. The results obtained from these mixtures were then compared with the performance of the baseline refrigerant, R600a.The study examined how the composition of R290 in the refrigerant mixture affects parameters such as Coefficient of Performance (COP), refrigerant mass flow rate, and power consumption rates. Additionally, the influence of compressor speed, evaporation temperature, and condensation temperature on the compressor's overall performance was investigated through steady-state experimental tests.

The key findings of the study include the following:

- An increase in the mass proportion of R290 in the mixture led to higher power consumption rates. However, this rise also resulted in a substantial increase in refrigerant mass flow rate, contributing to an overall improvement in COP.
- The optimal compressor speed was identified to be around 2100 rpm for the specific hermetic reciprocating compressor used in the study.
- The COP demonstrated an upward trend as the evaporation temperature increased and the condensation temperature decreased.
- The refrigeration cycle's COP using R290/R600a mixtures was found to be 10-20% higher compared to using R600a, depending on the refrigerant mixture's composition and the operational conditions.

Overall, the research showcases the potential of utilizing R290/R600a refrigerant mixtures in household refrigeration systems. This blend of refrigerants offers promising improvements in terms of energy efficiency and overall performance compared to the conventional R600a refrigerant.

Yongseok Jeon, Sunjae Kim, Dongwoo Kim, Hyun Joon Chung, Yongchan Kim have study on Performance characteristics of an R600a household refrigeration cycle with a modified two-phase ejector for various ejector geometries and operating conditions. The widespread use of household refrigerator-freezers has led to a significant portion of residential energy consumption.

Efforts to improve refrigeration system performance and address environmental concerns have prompted research into advanced technologies for system components. Traditional expansion devices, like capillary tubes and expansion valves, have limitations in energy recovery during the expansion process. A promising alternative is the two-phase ejector cycle, which can significantly recover energy lost during expansion. While past research mainly focused on the standard two-phase ejector cycle, the condenser outlet split (COS) ejector cycle has gained attention due to its advantages. The COS cycle divides refrigerant flow at the condenser outlet, yielding improved efficiency. Despite advancements, studies on COS ejector cycles are limited, particularly in household refrigeration.This study investigates the impact of ejector geometries on a small household refrigeration cycle using eco-friendly R600a refrigerant. The performance of the COS ejector cycle is analyzed under various conditions, including entrainment ratios, compressor speeds, and mixing section diameters. Entrainment ratio represents the secondary mass flow rate to primary mass flow rate ratio.Results show that the efficiency of the COS ejector cycle improves as the entrainment ratio decreases and the compressor speed increases, due to reduced expansion loss. At specific conditions, a maximum COP enhancement of 6.8% is achieved compared to the baseline cycle. The study proposes optimal ejector geometries for different operating scenarios.This research contributes valuable insights into the performance enhancement potential of the COS ejector cycle for small household refrigeration systems using R600a. The findings offer guidelines for designing efficient ejector systems, thereby improving energy efficiency and reducing environmental impact.

Y.S. Lee, C.C. Su have investigate on Experimental studies of isobutane (R600a) as the refrigerant in domestic refrigeration system. Refrigeration and air conditioning systems play a vital role in various industries, but the use of environmentally harmful refrigerants like CFCs and HCFCs has posed significant issues such as ozone layer depletion and contributing to the greenhouse effect. The phase-out of these refrigerants has been mandated to mitigate their adverse impacts. While R134a, a non-ozone depleting refrigerant, has been used, its high global warming potential raises concerns. Consequently, the development of alternative refrigerants like isobutane (R600a) and propane (R290) has gained traction due to their favorable thermodynamic properties, including low critical pressures and high enthalpy differences in two-phase regions.

However, hydrocarbons like R600a are flammable, potentially causing hazards from unintended leaks. For instance, R600a is prohibited in the USA and Japan due to its flammability, despite being utilized in European domestic refrigerators. Studies have explored mixtures of various refrigerants, such as R290/R134a and R134a/R600a. These investigations have shown that while the COP of R290/R134a mixtures may be lower than certain alternatives like R22 and R290, R134a/R600a mixtures can exhibit higher COP values than R12 and R134a. Interestingly, in hermetic vapor-compression systems, both R290 and R290/R600a mixtures have demonstrated improved performance compared to R12. However, limited attention has been given to domestic refrigerators employing pure R600a as the refrigerant. Therefore, this study aims to assess the performance of a small vapor-compression refrigeration system using R600a. Factors like capillary tubes, refrigeration loads, and cooling conditions are analyzed to understand their influence on the system's efficiency and behavior. This research fills a gap in the literature and contributes to the understanding of utilizing R600a in refrigeration systems while considering various operational parameters.

C S Choudharia, S N Sapalib have study on performance Investigation of Natural Refrigerant R290 as a Substitute to R22 in Refrigeration Systems. Refrigeration technology has had a profound impact on improving human living standards, with inventions like refrigerators and air-conditioners becoming essential for comfortable living. However, from its inception, the refrigeration industry has grappled with issues surrounding the safety and environmental impact of refrigerants. Despite ongoing efforts by researchers, the industry has still been a significant contributor to environmental degradation.

After initial challenges with natural refrigerants and concerns about their flammability, the discovery of CFCs and HCFCs marked a turning point for the industry. These compounds, introduced in 1930, gained popularity due to their favorable thermophysical properties and safety. However, their role in ozone layer depletion was identified in 1974, leading to the Montreal Protocol of 1987, which aimed to phase out CFCs and HCFCs. While efforts were made to replace them with HFCs, another environmental concern arose – global warming.

HFCs and other substances, although having lower ozone depletion potential (ODP), were found to have higher global warming potential (GWP). This prompted the search for environmentally friendly yet energy-efficient alternatives. This quest led researchers back to natural hydrocarbons like Propane (R290), which showed promise as a potential solution.

For decades, the use of flammable hydrocarbon refrigerants was restricted due to safety concerns. Propane (R290), initially recognized for its excellent thermo-physical properties in the 1920s, was overshadowed by the development of CFCs and HCFCs due to its flammability. However, with evolving technology and changing circumstances, the industry is now reconsidering R290 as a replacement for R22.

Numerous studies have explored Propane and its mixtures as alternatives. Researchers have investigated R290's performance compared to R22 in various applications, such as air conditioners and heat pumps. Findings have shown that R290 offers advantages like higher coefficient of performance (COP) and energy efficiency ratio (EER), although it may have slightly lower cooling capacity. The energy efficiency and thermodynamic performance of R290 are demonstrated to be competitive with R22 in various applications.

This study emphasizes the viability of using R290 as a substitute for R22, highlighting its potential benefits and analyzing its thermodynamic behavior in different scenarios. As the industry aims to strike a balance between performance and environmental responsibility, R290 stands as a candidate that aligns with both goals.

Zhan Liua , Minkai Baia, Haihui Tanc, Yunzhi Linga, Zhen Cao was study on Experimental test on the performance of a −80 °C cascade refrigeration unit using refrigerants R290-R170 for COVID-19 vaccines storage. The operating reliability and stability of the refrigeration system become extremely important due to the urgent demand for ultralow-temperature refrigerators around the world. A -80 oC ultralow-temperature cascade refrigeration system (CRS) is created in this study. In the high-temperature cycle and low-temperature cycle of CRS, respectively, the environmentally benign refrigerants R290 and R170 are used because to their low GWP and ODP potentials. In a Type-laboratory with a dry bulb temperature of 25.0 °C and a wet bulb temperature of 20.2 °C, the experimental measurement is carried out. Experimental research is done on the CRS freezer's pull-down and steady operation performance. Two compressors' intake and outlet temperatures and pressures are tracked, and the CRS's operational characteristics are examined. The temperature drop and temperature fluctuation variance of the air are measured using several temperature test points set up in the freezer. The CRS's operating power usage is likewise monitored throughout the entire procedure. It demonstrates that the created ultralow-temperature freezer is capable of producing and realizing the temperature of 80 °C.

Baomin Dai , Haining Yang , Shengchun Liu , Chen Liu , Tianhao Wu , Jiayi Li , Jiayi Zhao , Victor Nian was study on Hybrid solar energy and waste heat driving absorption subcooling supermarket CO_2 refrigeration system: Energetic, carbon emission and economic evaluation in China. The concept of a hybrid solar energy and waste heat-driven absorption subcooled carbon dioxide (CO_2/R744) booster refrigeration system (SE + WH) has been introduced as an innovative approach to enhance the energy efficiency of conventional CO_2 refrigeration systems used in supermarket applications. A comprehensive thermodynamic and energy conversion model has been developed for this system. To optimize its energy efficiency considering varying ambient temperature and solar radiation intensity, a two-dimensional golden section search algorithm has been employed.Taking into account the uneven distribution of solar energy and diverse meteorological conditions in China, the study has selected eight representative cities to evaluate the annual performance factor and life cycle carbon emissions. This assessment aims to quantify the potential energy savings and carbon emission reductions achievable by implementing this hybrid system.The hybrid solar energy and waste heat-driven absorption subcooled CO_2 booster refrigeration system exhibits significant improvements in comparison to the baseline system. At solar radiation intensity levels of 1200 W/m² and temperatures ranging from 0 to 35°C, the hybrid system achieves a COP enhancement of 3.05–42.30%. Notably, this system's discharge pressure can be lowered by 7.86% at an ambient temperature of 34°C.
In Haikou, the annual performance factor of the proposed hybrid system increases by 14.47%, and its life cycle carbon emissions are effectively reduced by 39.54%. Moreover, the payback period sees a reduction of 4.01% in Beijing and 3.37% in Shanghai. As a result, the novel configuration of the hybrid absorption subcooling subsystem is particularly recommended for regions with hot or warm climates and abundant solar energy resources. This innovative approach holds promise for improving the energy efficiency and environmental performance of refrigeration systems in commercial settings.

Kolthoum Missaoui, Abdelhamid Kheiri , Nader Frikha , Slimane Gabsi , Mohammed El Ganaoui have study on Heat storage in solar adsorption refrigeration systems: A case study for indigenous fruits preservation. The focus of this study is on heat storage within a solar-powered refrigeration system specifically designed for preserving indigenous products in a cold room with positive temperatures. A primary objective is to emphasize the significance of heat storage and the appropriate selection of coupling, positioning, and technology for thermal heat storage in these systems. This ensures effective energy management and enhances the system's operational flexibility.

A novel system configuration has been developed, which eliminates the direct connection between the solar collectors and the adsorption chiller used in the directly driven chiller, while introducing a specialized regulation system to manage the temperature of the water supplied to the adsorption chiller. This new design outperforms existing configurations in terms of efficiency and system stability under the same solar collector area. It is demonstrated that incorporating a Hot Water Tank (HWT) for heat storage leads to extended cooling production durations, improved stability, and reduced fluctuations in hot water temperature within solar adsorption chillers.

The study highlights the critical role played by the cycle time duration of the adsorption chiller, as well as the volume of the HWT, in determining system performance. Furthermore, it demonstrates that utilizing a stratified HWT, which maintains distinct temperature layers, is more advantageous compared to a fully mixed HWT. Using a total solar collector area of 84.53 m^2, a 3 m^3 hot water tank, and a cycle time of 1200 seconds, the proposed configuration achieves a solar fraction of 86% when connected to stratified heat storage technology. Meanwhile, the system equipped with a mixed hot water tank achieves a solar fraction of 80%.

In conclusion, the study underscores the importance of heat storage and offers insights into optimal system configurations and components to achieve enhanced energy efficiency and stability in solar-powered refrigeration systems tailored for preserving indigenous products.

Jos´e Manuel Luj´an , Jos´e Galindo , Vicente Dolz , Alberto Ponce-Mora have investigate on Optimization of the thermal storage system in a solar-driven refrigeration system equipped with an adjustable jet-ejector. The current paper presents a numerical study that explores the effects of different thermal storage capacities and thermal power consumption strategies in a solar-driven air-conditioning system utilizing refrigerant R1234yf. The computational model is supplied with hourly climatic data, including solar irradiance and ambient temperature, based on the typical meteorological conditions of a Mediterranean location. The study places particular emphasis on understanding the dynamic behavior of the refrigeration system, the solar collector, and the sensible heat storage tank.

The investigation highlights the importance of system dynamics, considering that the cooling requirements typically align with the hours of sunlight. This dynamic connection suggests that smaller thermal storage tank volumes are more effective, as they allow for rapid heating during tank discharges. The research focuses on finding an optimal balance between key performance indicators, such as refrigeration capacity, thermal coefficient of performance (COP), and the system's ability to maintain suitable thermal levels in the heat reservoir.

In the context of a parabolic trough collector span measuring 7.1 meters, the study suggests that a thermal power consumption of 13.3 kW offers a favorable compromise among various performance metrics. This balance helps achieve satisfactory refrigeration capacity, COPth, and system reliability, ensuring adequate thermal levels within the heat reservoir. Overall, the study contributes valuable insights into optimizing solar-driven air-conditioning systems using refrigerant R1234yf, emphasizing the significance of dynamic responses and storage capacity in system performance.

Devendra Raut, Vilas R. Kalamkar have study on A review on latent heat energy storage for solar thermal water-lithium bromide vapor absorption refrigeration system. Refrigeration has evolved into a fundamental aspect of human comfort and currently accounts for nearly 20% of total energy consumption within the commercial sector. The reliance on fossil fuels to power conventional refrigeration systems presents a grave concern, as it contributes to global warming due to carbon emissions during electricity generation. Additionally, the utilization of conventional refrigerants further exacerbates environmental issues, including global warming and ozone layer depletion. To address these challenges, the vapor absorption refrigeration system (VARS) utilizing water-lithium bromide (H_2O-LiBr) emerges as a promising solution. This unique refrigerant-absorbent pair circumvents the release of harmful residues. The integration of a H_2O-LiBr VARS with clean energy sources, particularly solar energy, holds the potential to entirely eliminate carbon emissions. While solar energy stands as the cleanest and most abundant energy source worldwide, its intermittency poses a limitation. Enter latent heat storage (LHS), an innovative and burgeoning technology that effectively stores solar heat, ensuring uninterrupted operation of solar thermal-driven systems. By coupling LHS with suitable phase change materials (PCMs) and adept storage tank designs, heat supply for VARS operation can be reliably furnished.

This comprehensive review delves into the realm of PCM selection, meticulously discussing the most suitable and proficient PCMs for VARS applications. The discourse extends to the latest advancements, addressing characterization, limitations, remedies, and progress in this arena. The insights garnered facilitate the informed choice of appropriate PCMs for VARS. Furthermore, an exhaustive exploration of diverse LHS storage tank designs is provided, underlining key findings that warrant consideration during the design phase for VARS-associated LHS systems. Techniques aimed at augmenting performance, such as the incorporation of fins, encapsulation methods, and additive utilization, are intricately examined. Delving into the current state of research, this review delves into the integration of LHS with VARS, revealing a promising trajectory for the technology. The future landscape is discerned from the implications gleaned from published research endeavors, indicating that refinements in organic and inorganic PCMs are necessary to optimize heat storage. Notably, the integration of LHS can notably extend the operational hours of heat-driven VARS systems. However, the trajectory of latent heat storage in VARS hinges upon the adoption rate of solar thermal VARS technology. In summation, this comprehensive review stands as a definitive reference, adeptly guiding the planning, design, and development of latent heat storage solutions for vapor absorption refrigeration systems in the pursuit of sustainable and energy-efficient cooling technologies.

Alireza Riahi , Mohammad Behshad Shafii was study on Parametric study of a vapor compression refrigeration system integrated with a PCM storage tank for increasing condenser sub-cooled temperature. This study delves into a comprehensive parametric examination of a vapor compression refrigeration system, intricately integrated with a Phase Change Material (PCM) storage tank. The primary objective is to elevate the condenser sub-cooled temperature, a critical factor in system efficiency enhancement, particularly pertinent on the hottest days in Tehran. Employing EES software, the investigation meticulously analyzes diverse parameters encompassing comfort zone temperature, condenser and evaporator temperatures, and heat transfer coefficient adjustments corresponding to PCM tank ice formation thickness.By scrutinizing the system's performance vis-a-vis varying parameters of the PCM storage tank, intriguing insights emerge. The inclusion of the PCM storage tank, while leading to an increase in daily electric energy consumption from 20.86% to 30.63% compared to the conventional setup, remarkably augments accessible cooling energy during cold energy release, elevating it from 39.67% to an impressive 54.60%. This translates to a discernible increment in accessible cooling energy throughout the day, ranging from 3.11% to 3.59%. Notably, the introduction of the PCM tank does impact the total daily Coefficient of Performance (COP), causing a reduction from 14.68% to 20.7% in comparison to the conventional unit.

In summary, this investigation offers a nuanced understanding of the intricate dynamics between a vapor compression refrigeration system, PCM storage tank integration, and their collective impact on system performance. The study's findings illuminate the trade-offs and potential gains, shedding light on the feasibility and efficiency implications of utilizing PCM storage tanks to elevate condenser sub-cooled temperatures in demanding climatic conditions.

Mengyu Song, Lin Wang, Junfei Yuan, Zhanwei Wang, Xiuzhen Li, Kunfeng Liang have study on Proposal and parametric study of solar absorption/dual compression hybrid refrigeration system for temperature and humidity independent control application. Solar absorption refrigeration technology plays a pivotal role in enhancing building energy efficiency and curbing emissions. This study capitalizes on the energy cascade utilization concept and introduces an innovative solar absorption/dual compression hybrid refrigeration (SADC-HR) system. This system integrates a solar-driven single effect absorption refrigeration (SSAR) subsystem with a power-driven dual-source dual-compression refrigeration (PDCR) subsystem. The latter combines an air-cooled compression refrigeration (ACR) cycle with a water-cooled compression refrigeration (WCR) cycle, effectively catering to all-weather space cooling and heating requirements. The SADC-HR system achieves a cascade of cold energy production and utilization, enabling independent control of temperature and humidity in air conditioning.A comprehensive thermodynamic model of the SADC-HR system is developed to assess its performance and operational parameters. Comparisons with two conventional systems are conducted. Results unveil optimal conditions for the SSAR subsystem, pinpointing a generating temperature of 70°C and an evaporating temperature of 18°C for attaining minimal power consumption at a low solar intensity of 450 W/m². Remarkably, the SADC-HR system showcases enhanced economic viability, with its solar collector area being 55.79% and 34.75% smaller compared to the conventional SSAR and solar absorption-compression cascade refrigeration (SA-CCR) systems, respectively, at the same solar intensity.

Furthermore, the proposed system demonstrates superior energy-saving performance and reduced environmental impact. In contrast to the conventional SA-CCR system at a solar intensity of 800 W/m², the SADC-HR system reduces power consumption by an impressive 61.47%, significantly contributing to CO2 emissions reduction. A practical case study underscores these benefits, showcasing a notable 25.32% reduction in total seasonal electricity consumption in the SADC-HR system, translating to a decrease of 21,580.66 kg of CO2 emissions compared to the conventional ACR system.

In essence, this study illuminates the promising potential of the SADC-HR system in advancing sustainable and efficient cooling and heating solutions through innovative hybridization and the harnessing of energy cascades.

Jing Xu , Wei Zhang , Zhiliang Liu , Quanwen Pan , Ruzhu Wang , Tianshu Ge have study on Energy and exergy analyses of a hybrid adsorption refrigeration system for simultaneous production of cold water and dry air. The limitations of current adsorption refrigeration systems, which typically produce either cold water or cold dry air due to constraints in dehumidification methods, hinder their applicability in scenarios requiring multiple cooling outputs. To overcome this challenge, this study presents a novel approach: a hybrid adsorption refrigeration system employing efficient desiccant-coated heat exchangers to generate both cold water and dry air by effectively utilizing input heat sources. Through comprehensive experimental analysis encompassing both energy and exergy perspectives, the performance of the hybrid system is rigorously assessed.

Results demonstrate that the hybrid configuration successfully delivers simultaneous cold water and dry air outputs utilizing a heat source ranging from 50 to 80°C. The presence of a low-temperature cooling water is shown to enhance system performance, while an optimal input hot water temperature is identified. At a coolant-side temperature of 25°C, the Coefficient of Performance (COP) achieves its peak value of 0.238 at a heat source temperature of 60°C.

Similarly, the highest exergetic efficiency, quantified at 13.9%, is attained with a 50°C hot water supply. Elevating inlet air temperature or relative humidity contributes to COP enhancement, albeit with negligible impact on exergetic efficiency.

When juxtaposed with traditional adsorption air conditioning systems, the hybrid approach boasts a broader spectrum of input hot water temperatures, proving particularly advantageous in terms of cooling exergy and exergetic efficiency. Notably, this pioneering hybrid system marks a pivotal advance by enabling adsorption refrigeration to simultaneously produce dual cooling outputs—cold water and dry air. This innovation is poised to extend the reach of adsorption refrigeration to fully automated industrial domains, promising transformative applications.

Håkon Selvnes , Yosr Allouche , Armin Hafner , Christian Schlemminger , Ignat Tolstorebrov have study on cold thermal energy storage for industrial CO_2 refrigeration systems using phase change material: An experimental study. Refrigeration systems used in industrial food processing plants are known for their substantial electricity consumption and frequent high demand for power. Integrating Cold Thermal Energy Storage (CTES) technology into these refrigeration systems offers a solution to reduce peak power requirements and achieve more balanced power usage by separating the supply and demand of the cooling load. This research paper focuses on the design and performance of a CTES unit, which employs a unique configuration involving a pillow plate heat exchanger (PP-HEX) submerged within a low-temperature phase change material (PCM) as the storage medium.

This study stands out for its pioneering approach, as it is one of the initial experimental investigations to demonstrate a large-scale technical solution that effectively coordinates the evaporation and condensation processes of the refrigeration system with the melting and solidification of a low-temperature PCM within the same heat exchanger. The performance of this CTES unit was thoroughly examined, utilizing CO_2 as the refrigerant and a commercial PCM with a phase change temperature of -9.6°C.

The investigation encompassed comprehensive tests on the charging and discharging processes of the plates-in-tank CTES unit. The findings revealed that the charging time was primarily influenced by the refrigerant's evaporation temperature, whereas the discharge rate and the total energy discharged throughout the cycle increased when the refrigerant's condensing temperature was elevated. Interestingly, using a plate pitch of 30 mm yielded the highest average discharge rate and total energy discharged over the cycle, reaching 9.79 kW and 17.04 kWh, respectively. What's remarkable is that this adaptable CTES-PCM unit can be tailored to suit diverse refrigeration load characteristics and temperature requirements. This adaptability is achieved by adjusting the geometry of the PP-HEX and selecting different types of PCM as the storage medium. In essence, this research introduces a promising avenue for enhancing the efficiency and flexibility of refrigeration systems in industrial contexts, offering potential benefits in both power consumption optimization and load management.

Mohamed G. Gado, Shinichi Ookawara , Sameh Nada , Hamdy Hassan have study on Performance investigation of hybrid adsorption-compression refrigeration system accompanied with phase change materials -Intermittent characteristics. This study investigates the intermittent performance of hybrid adsorption-compression refrigeration systems, particularly in the context of cold storerooms. The hybrid system effectively utilizes ultra low-grade heat (65°C) and employs natural refrigerants. The dual-bed adsorption system utilizes a silica gel/water (R718) working pair, while the compression system incorporates isobutane (R600a). Additionally, a phase change material (PCM) is integrated into the system to extend compressor off durations and enhance the stabilization of air temperature within the cold storeroom.
The research involves the development of mathematical models using the MATLAB/SIMULINK framework, which are validated against relevant literature. The study examines the dynamic behavior of key indicators in the hybrid system, including temperature profiles, cooling capacity, Coefficient of Performance (COP), electric power, and electricity demand, considering intermittent operational patterns. These results are compared to a baseline system.
Findings indicate that the hybrid system's intermittent operation mode yields superior energy savings (37%) compared to continuous operation (31.63%). Furthermore, the hybrid system achieves a COP of approximately 4 at steady-state, contrasting with the baseline system's COP of around 2.3. The incorporation of PCM mitigates air temperature fluctuations within the cold storeroom, leading to reduced cyclic operations and a 24.1% reduction in on-time ratio compared to the baseline system (34.8%), albeit with a slight reduction in system COP.

In conclusion, the integration of hybrid refrigeration systems with PCM demonstrates notable advantages over conventional compression systems. This research underscores substantial energy savings, enhanced temperature stability, and improved efficiency, particularly in settings with intermittent operation requirements such as cold storerooms.

Houda Eletri1, Elias M. Salilih, Mouna HAMED, Ali FELLAH have study on Performance analysis of a hybrid solar-driven cooler for refrigerator vehicle. This research delves into exploring the annual efficiency of an innovative hybrid solar-driven cooling system designed for refrigerator vehicles. The central driving force of this cooling system is a DC compressor, powered by a photovoltaic (PV) array .In instances of heightened cooling demand exceeding the DC compressor's capacity, an AC compressor, energized by the car's alternator, steps in to provide additional cooling assistance. The study encompasses a meticulous electrical modeling of the PV array, executed through a set of mathematical equations, validated against the manufacturer's empirical test data. The transient electrical power generation of the PV array is analyzed in detail. The research also delves into investigating how solar irradiation and ambient temperature influence the PV module's performance.

On the refrigeration cycle front, the study conducts an exhaustive thermodynamics and heat transfer analysis of the cycle's operation. The examination specifically considers the impact of ambient temperature and refrigerator compartment temperature on the refrigeration cycle's efficiency. It emerges that as ambient temperature increases, both the PV panel's efficiency and the refrigeration cycle's effectiveness decrease. On the other hand, raising the temperature within the refrigerator compartment enhances the performance of the refrigeration cycle.

In summary, the study concludes that the hybrid solar-driven cooling system, tailored for refrigerator vehicles, offers a promising avenue for sustainable cooling solutions. It underscores the significance of understanding and optimizing both the PV array's electrical behavior and the thermodynamics of the refrigeration cycle to achieve enhanced overall system performance, taking into account external factors such as solar irradiation, ambient temperature, and compartment temperature.

Mohamed G. Gado , Sameh Nada , Shinichi Ookawara , Hamdy Hassan was investigated on Energy management of standalone cascaded adsorption-compression refrigeration system using hybrid biomass-solar-wind energies. This study explores the viability of a novel hybrid renewable energy system comprising biomass, solar, and wind sources to power cascaded adsorption-compression refrigeration systems. The system's performance is compared with a conventional compression system driven by the same input energy. Two renewable energy scenarios are presented: biomass-solar-battery (Scenario-I) and biomass-solar-wind-battery (Scenario-II). These scenarios autonomously operate the cascaded adsorption-compression system by utilizing biomass, thermal waste heat from photovoltaic/thermal collectors, and wind energy. Excess electricity is converted into heat via an electric heater. The analysis is conducted using meteorological data from New Borg El-Arab city, Egypt.

Results show that Scenario-I proves more economically efficient, with a refrigeration cost of $0.235 per kWh compared to $0.237 per kWh for Scenario-II. In Scenario-I, photovoltaic/thermal collectors meet 100% of the required electric load and produce an excess of 16.6 kWh, while Scenario-II generates 15 kWh of surplus electricity due to fewer photovoltaic/thermal collectors. For both scenarios, biomass energy caters to most of the thermal demand. A trade-off between the proposed cascaded adsorption-compression cycle and a renewable-based conventional compression cycle is conducted. For the conventional compression cycle, photovoltaic-battery (Scenario-III) and photovoltaic-wind-battery (Scenario-IV) systems are proposed. Scenario-III yields a lower annual cost of $2714 compared to $4045 for the cascaded system, particularly in Scenario-I.

Overall, using a blend of renewable energy sources to power cooling and refrigeration systems presents a promising avenue to curtail energy demands, mitigate global warming, and address climate change concerns. This study highlights the potential of such hybrid systems in contributing to sustainable energy solutions.

Muhammad Tawalbeh , Rana Muhammad Nauman Javed , Amani Al-Othman , Fares Almomani have study on Salinity gradient solar ponds hybrid systems for power generation and water desalination. Solar energy stands out as a preferred energy source due to its affordability, ease of collection, abundant availability, and its capacity to mitigate pollution and water scarcity. Solar ponds, which harness low-grade thermal energy, can efficiently absorb and store solar radiation. Ongoing research and advancements in solar pond technology have been driven by the potential synergy with various heat storage systems and heat extraction mechanisms. This article presents a comprehensive review of recent achievements in solar pond technologies, particularly focusing on salinity gradient solar ponds (SGSPs) for hybrid solar power generation and water desalination systems. The applications of these technologies extend to refrigeration, air-conditioning, and domestic as well as industrial process heating.

The review highlights that the principal challenge facing large-scale solar pond operations is their relatively low thermal efficiency. This hurdle, however, can be addressed by maintaining stable salinity and temperature gradients along with optimizing zone thicknesses. The review notably emphasizes novel advancements in hybrid systems and poly-generation energy systems, which aim to enhance the overall energy and exergy efficiency of salinity gradient solar ponds. Notably, the integration of salt gradient solar pond hybrid systems has yielded remarkable outcomes, including achieving a maximum lower convective zone temperature of 90°C, exceeding 50% energy/exergy efficiency, and generating up to 5 MW of power.

In one instance, an independent desalination unit demonstrated about 54% exergy efficiency and produced around 2381 m^3 (approximately 73.3% annually) of potable water. These findings underscore the potential of salt gradient solar pond hybrid systems to significantly improve both power generation and water desalination efficiency, which holds promise for researchers in the field. This review serves as a comprehensive reference for emerging researchers and highlights the potential of integrating advanced solar pond technologies into diverse energy applications.

2.3 GAP OF KNOWLEDGE

The development of renewable energy is increasing worldwide because of the growing demand on energy, high oil prices, and concerns of environmental impacts. I studied so many journals thoroughly to understand the related concept and I found that their something was outdated and no relevant but some papers have new knowledge, techniques and concepts which are needed to add in the new research papers. Most of the papers of refrigeration system are not concern about the environment impacts, they used CFCs and HCFCs refrigerants which are directly effects our ozone layer ,Ozone layer is the protected shield of UV rays, So it decreases ozone depletion potential (ODP). That reason we use natural refrigerant isobutane (R600a) in our refrigeration system. We also concern about the global warming, that reason we used solar water heating system to make a super heater. In this project ,I face many obstacles to achieve this optimal HRS ,I failed to increase pressure of the refrigerant at the inlet of compressor except temperature. I have a huge interest to research on natural refrigerant. There are very less papers on natural refrigerant in air conditioning system compare to other fields .There is a huge scope in this field to invent new technology for the society. There are some paper where we find the new technology like mixing (by percentage) two natural refrigerants (R600a), (R290) to make a new refrigerants which properties are better than individual refrigerant ,Solar PV refrigeration system,R600a with a modified two phase ejector, modified Solar collector ,solar absorption refrigeration system etc. Their used many software for simulation like TRANSYS, MATLAB, HOMER etc. So I used Matlab simulation software to make a optimal HRS where we concern about the natural refrigerants, GWP, ODP, Environmental impacts and also a cost effective system.

2.4 PROBABLE SOLUTION

In addressing the critical concerns of global warming potential (GWP), ozone depletion potential (ODP), environmental impacts, and cost-effectiveness within refrigeration systems, a promising solution emerges. Numerous studies have extensively explored the utilization of natural refrigerants and innovative techniques to enhance their properties. In this project, we propose a novel approach that integrates the refrigeration system of a natural refrigerant, Isobutene (R600a), with a solar water heating system (SWHS) serving as a super heater by the help of the Matlab Simulation software. We aim to create an optimized system that not only addresses environmental impacts but also focuses on GWP, ODP, and cost-effectiveness. Isobutene (R600a) is selected as the refrigerant due to its low GWP and ODP values, making it a more environmentally friendly option compared to conventional refrigerants. Incorporating a solar water heating system as a super heater aligns with sustainable practices, utilizing clean and renewable energy sources to enhance the c.o.p of the refrigeration process. The synergy between Isobutene and the solar water heating system could lead to improved overall system performance, reduced energy consumption, and minimized environmental impacts.

Through the implementation of the Matlab Simulation software, we will model and analyze the interactions between the Isobutene refrigerant based refrigeration system and the solar water heating system. This simulation-based approach enables us to fine-tune various parameters and configurations to achieve an optimal system design. Our focus extends beyond c.o.p gains and cost-effectiveness, encompassing the reduction of GWP and ODP, which are critical factors in mitigating climate change and protecting the ozone layer.

By developing an integrated refrigeration system that harmonizes natural refrigerants and solar energy, we anticipate significant strides in environmental responsibility and sustainability. The outcomes of this project could contribute to the creation of a refrigeration solution that not only aligns with current environmental priorities but also offers economic benefits for today's society. This holistic approach exemplifies the potential of combining innovative technologies to address pressing global challenges while simultaneously providing practical and cost-effective solutions for modern refrigeration needs.

2.5 CONCLUSION

From the above chapter, we review almost all journals related in this field, gathered different techniques and methodology. It is clear that designing of HRS with natural refrigerant is mainly based on software analysis and it depends on different parameters. In this chapter there have been gathered different technique of optimization for designing renewable energy based hybrid refrigeration system. In the base of earlier work, gap of knowledge, probable solution have been described in this chapter. Next chapter will discuss about the hybrid system configuration of the system.

CHAPTER 3

HYBRID SYSTEM CONFIGURATION

3.1 INTRODUCTION

In the world of finding better ways to produce energy that doesn't harm the environment, experts are looking at combining different technologies. This can help us meet our growing energy needs without causing as much pollution. This paper talks about a new idea where two systems are combined together: one is a cooling system that uses a natural and eco-friendly material called isobutane, and the other is a system that uses sunlight to heat water. When these two systems work together, they can save energy and do not pollute the environment.

This is especially important in India, where we need a lot of energy. In the past, I learned that by 2021, India had already done a lot to use renewable energy like solar power. They had set up enough solar panels to make more than 40 gigawatts of energy from the sun. The government's goal was to make 175 gigawatts of renewable energy by 2022, and a big part of that was supposed to come from the sun. Also, solar water heaters were getting popular in homes and businesses, hospitals.

Another thing is that some chemicals we use in cooling things can be bad for the environment. But people are trying to find better options. Isobutane is a natural chemical that can be used for cooling without causing as much harm. It doesn't add to global warming, which is important.

So, this new idea of mixing the cooling system with the solar water heating system makes a lot of sense in India. By using a computer program called MATLAB, experts are going to see how this hybrid refrigeration system works. They want to figure out if it's a good idea and if it can save energythen it will be used all around India. This way, we can get the energy we need without hurting the planet too much. It's a smart way of using new ideas and helping the environment at the same time.

3.2 DESIGNING OF HYBRID REFRIGERATION SYSTEM MODEL

In this Hybrid Refrigeration system, basically two individual systems are used to combine to make a hybrid refrigeration system. They are-

1. Refrigeration system with natural refrigerant
2. Solar Water Heating System

At the end of this design, both system combined and make a Hybrid refrigeration system which is shown in fig.3.3.

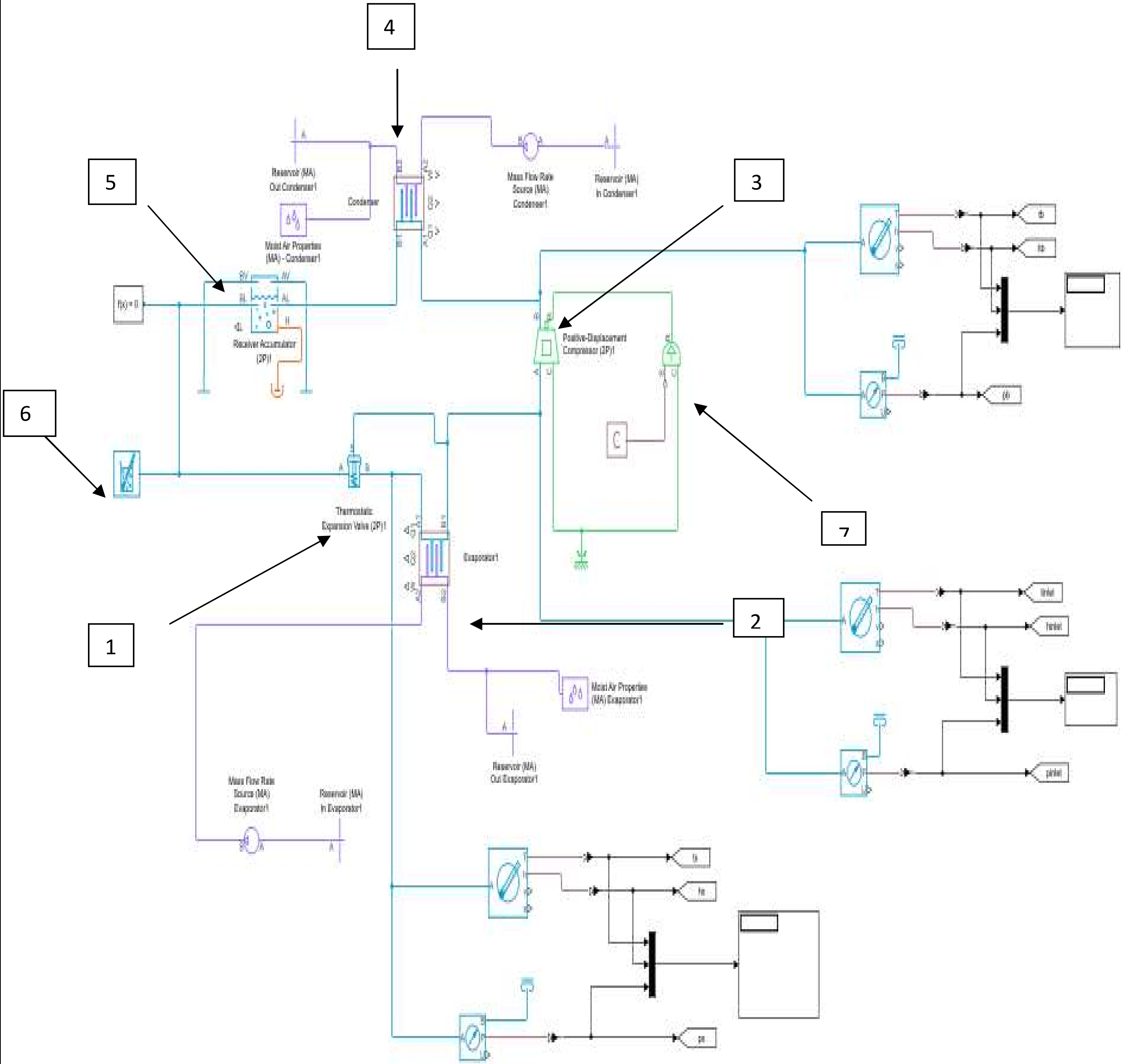

Fig.3.1 Refrigeration system with natural refrigerant

1. Thermostatic Expansion Valve, 2. Evaporator, 3.Positive displacement compressor, 4 Condenser, 5. Accumulator Receiver, 6. Two phase fluid properties (R600a), 7.Ideal angular velocity source,

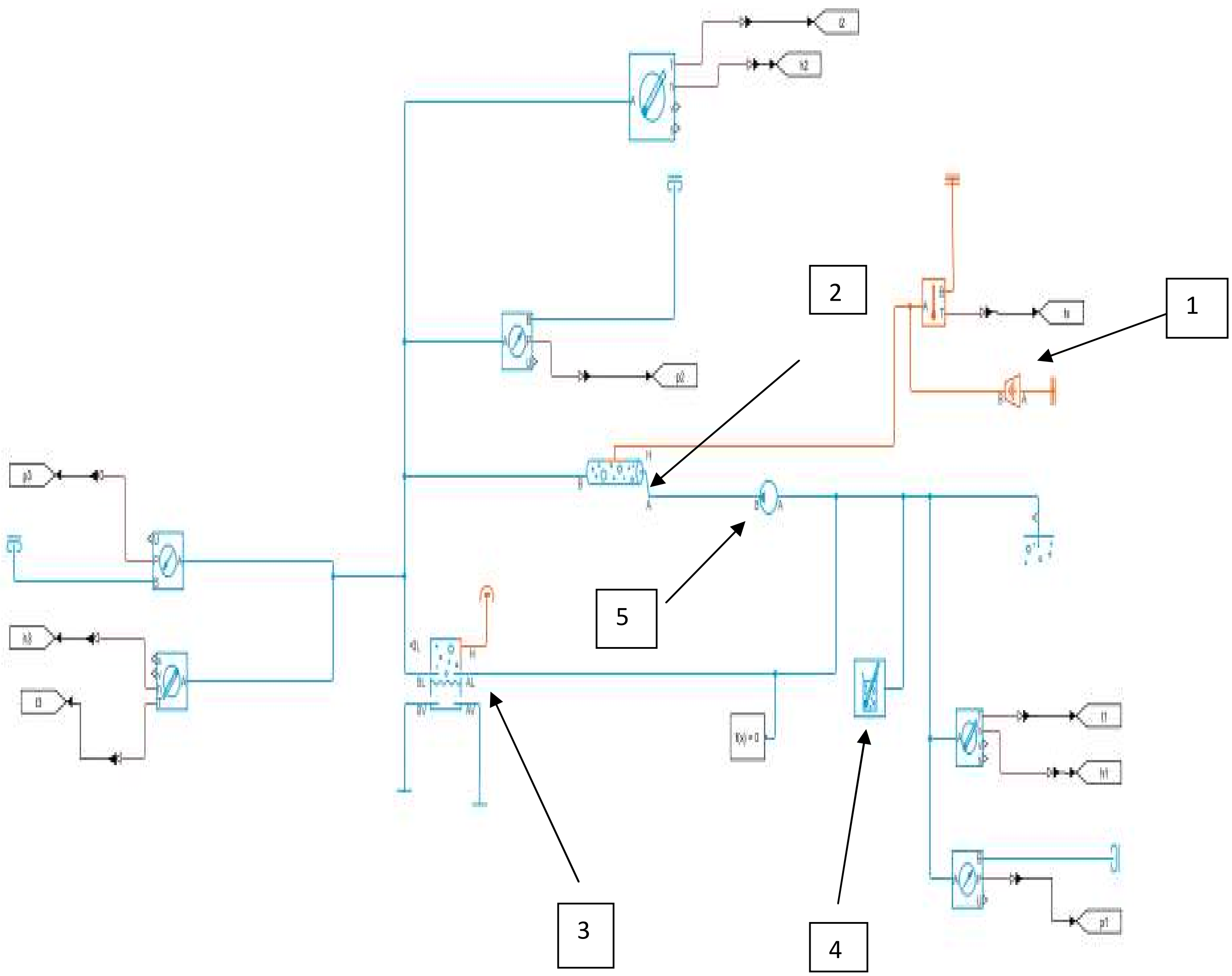

Fig.3.2 Solar Water Heating System

1.Heat flow rate source , 2. Pipe, 3.Receiver Accumulator, 4.Two-Phase Fluid Properties (Water), 5. Mass flow rate source.

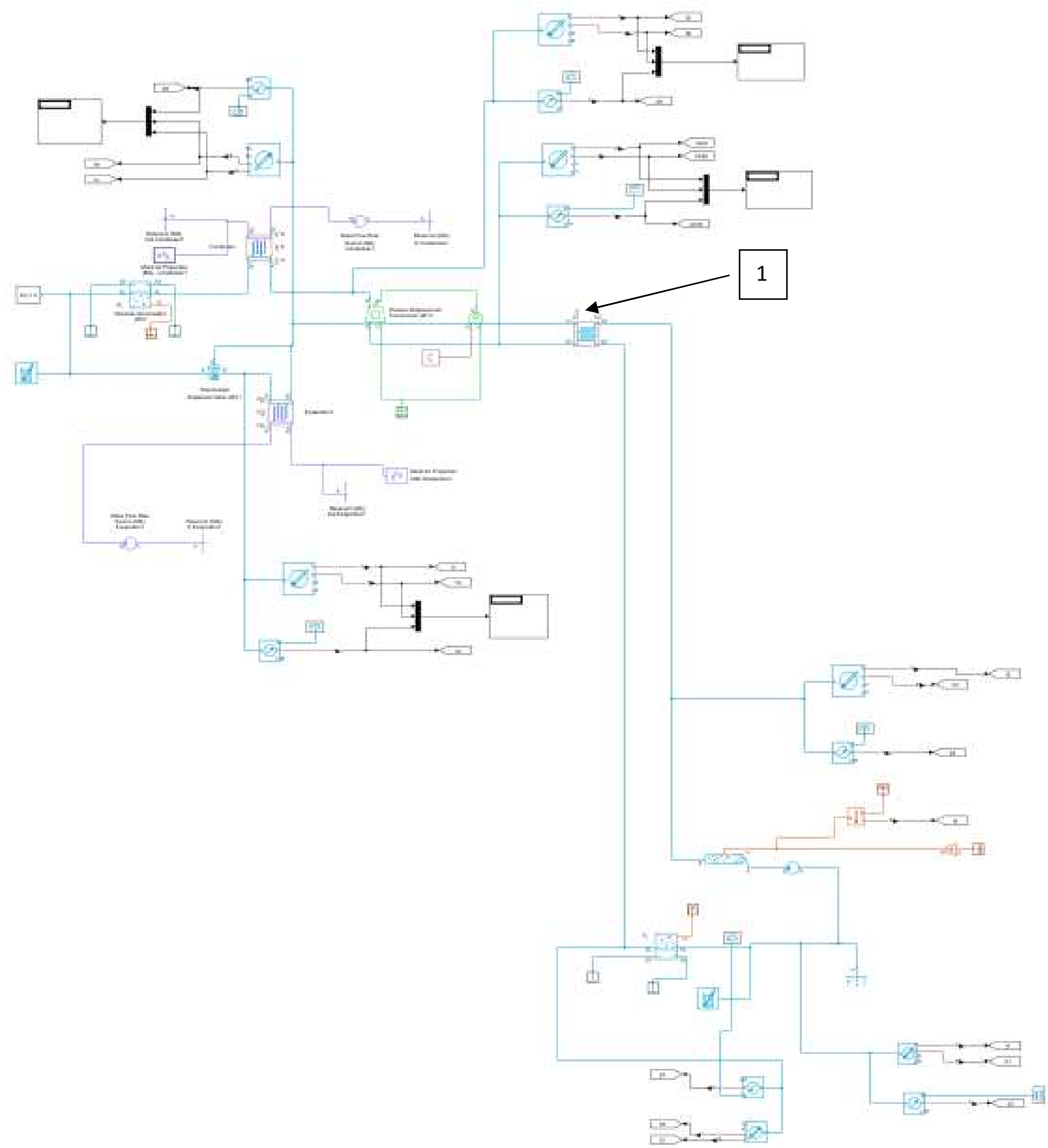

Fig.3.3 Combined System (Hybrid System)

1.Heat Exchange

3.3 STANDARD CONFIGURATION OF NORMAL REGRIGERATION SYSTEM

There are four important parts in standard refrigeration system, they are -1.Evaporator, 2.Compressor, 3.Condensor, 4.Expension valve. Here we discussed the specification of all components which is mentioned below. This specification is consider based on the natural refrigerant isobutane (R600a).All data are collected from the matlab simulation model, figure shown in fig.3.1.

EVAPORATOR					
Configuration	Specification	Two-Phase Fluid 1		Moist Air 2	
Flow arreengment at nominal operating condition	Cross flow – Both fluids flow A to B	Operating condition	Heat transfer from moist air to two-phase fluid	Operating condition	Heat transfer from moist air to two-phase fluid
Cross-section are at point A1(m^2)	pi*0.02^2/4	Nominal mass flow rate (kg/s)	0.1	Nominal mass flow rate (kg/s)	1.2*1.2
Cross-section are at point B1(m^2)	pi*0.02^2/4	Nominal evaporating temperature (k)	240	Nominal inlet temperature (k)	298
Cross-section are at point A2(m^2)	0.4^2	Nominal inlet specific enthalpy (kJ/kg)	290	Nominal inlet pressure drop (Mpa)	0.101325
Cross-section are at point B2(m^2)	0.4^2				

Table no.3.1 Evaporator configuration

COMPRESSOR					
Nominal mass flow rate (kg/s)	.1	Mechanical efficiency	0.9	Nominal condensing temperature (k)	320
Nominal shaft speed(rpm)	1000	Inlet area at port A(m^2)	pi*0.02^2/4	Nominal evaporating temperature (k)	300
Polytropic exponent	1.2	Outlet area at port B(m^2)	pi*0.02^2/4		

Table No.3.2 Compressor configuration

CONDENSER					
Configuration	Specification	Two-Phase Fluid 1		Moist Air 2	
Flow arrangement at nominal operating condition	Cross flow – Both fluids flow A to B	Operating condition	Heat transfer from two-phase fluid to moist air	Operating condition	Heat transfer from moist air to two-phase fluid
Cross-section are at point A1(m^2)	pi*0.02^2/4	Nominal mass flow rate (kg/s)	0.1	Nominal mass flow rate (kg/s)	1.2*1.5
Cross-section are at point B1(m^2)	pi*0.02^2/4	Nominal condensing temperature (k)	303	Nominal inlet temperature (k)	290
Cross-section are at point A2(m^2)	0.4^2	Nominal inlet temperature (kJ/kg)	490	Nominal inlet pressure drop (Mpa)	0.101325
Cross-section are at point B2(m^2)	0.4^2				

Table No.3.3 Condenser configuration

EXPANSION VALVE					
Nominal evaporating capacity (kw)	3.5	Nominal condensing temperature (k)	303	Nominal evaporating temperature (k)	263
Maximum evaporating capacity (kw)	3.5 *1.5	Cross-section are at ports A and B (m^2)	pi*0.02^2/4		

Table no.3.4 Expansion configuration

3.4 STANDARD CONFIGURATION OF SOLAR WATER HEATING SYSTEM

There are basically three important component, they are – 1.Sun (source of solar radiation or thermal energy), 2.Solar collector (pipe), 3.Storage system (Water tank). This system is basically a replica of solar thermal system, shown in fig.3.2. All specifications are obtained according to the optimal design. Data is collected from the optimal design from matlab simulation software.

Incident radiation (watt)	Pressure in Water Tank (bar)	Temperature in Water Tank (degree centigrade)	Temperature after super heating (degree centigrade)	Pressure after super heating (bar)
600	.2	60	45	.2

Table No.3.5 Solar Water Heating System

PIPE		WATER TANK		TWO-PHASE FLUID PROPERTIES	
Length(m)	1.5	Total tank volume(m^3)	1.5	Two-Phase fluid	Water(R-718)
Cross-section area (m^2)	0.01	Cross-section area (m^2)	0.5	Initial Pressure(Mpa)	0.101325
Initial pressure (Mpa)	0.101325	Initial pressure(Mpa)	0.1	Mass flow rate(kg/s)	0.1
Initial Temperature (degC)	25	Ater pressure gain (Mpa)	0.2		

Table No.3.6 Solar Water Heating System Pipe and Water Tank

3.5 HYBRID REFRIGERATION SYSTEM CONFIGURATION

This is a combination of NRS and SWHS shown in fig.3.3.In this system, there is one extra component is used called heat exchanger except all components are same compare to the NRS and SWHS. This specification is obtained based on the optimal system design and all the data is collected from the optimal model from matlab simulation software.

EVAPORATOR					
Configuration	Specification	Two-Phase Fluid 1		Moist Air 2	
Flow arreengment at nominal operating condition	Cross flow – Both fluids flow A to B	Operating condition	Heat transfer from moist air to two-phase fluid	Operating condition	Heat transfer from moist air to two-phase fluid
Cross-section are at point A1(m^2)	pi*0.02^2/4	Nominal mass flow rate (kg/s)	0.1	Nominal mass flow rate (kg/s)	1.2*1.2
Cross-section are at point B1(m^2)	pi*0.02^2/4	Nominal evaporating temperature (k)	240	Nominal inlet temperature (k)	298
Cross-section are at point A2(m^2)	0.4^2	Nominal inlet specific enthalpy (kJ/kg)	290	Nominal inlet pressure drop (Mpa)	0.101325
Cross-section are at point B2(m^2)	0.4^2				

Table no.3.7 Evaporator configuration

COMPRESSOR					
Nominal mass flow rate (kg/s)	0.1	Mechanical efficiency	0.9	Nominal condensing temperature (k)	360
Nominal shaft speed(rpm)	1000	Inlet area at port A(m^2)	pi*0.02^2/4	Nominal evaporating temperature (k)	315
Polytropic exponent	1.2	Outlet area at port B(m^2)	pi*0.02^2/4		

Table No.3.8 Compressor configuration

CONDENSER					
Configuration	Specification	Two-Phase Fluid 1		Moist Air 2	
Flow arrangement at nominal operating condition	Cross flow – Both fluids flow A to B	Operating condition	Heat transfer from two-phase fluid to moist air	Operating condition	Heat transfer from moist air to two-phase fluid
Cross-section are at point A1(m^2)	pi*0.02^2/4	Nominal mass flow rate (kg/s)	0.1	Nominal mass flow rate (kg/s)	1.2*1.5
Cross-section are at point B1(m^2)	pi*0.02^2/4	Nominal condensing temperature (k)	303	Nominal inlet temperature (k)	290
Cross-section are at point A2(m^2)	0.4^2	Nominal inlet temperature (kJ/kg)	490	Nominal inlet pressure drop (Mpa)	0.101325
Cross-section are at point B2(m^2)	0.4^2				

Table No.3.9 Condenser configuration

EXPANSION VALVE					
Nominal evaporating capacity (kw)	3.5	Nominal condensing temperature (k)	303	Nominal evaporating temperature (k)	263
Maximum evaporating capacity (kw)	3.5 *1.5	Cross-section are at ports A and B (m^2)	pi*0.02^2/4		

Table No.3.10 Expansion configuration

HEAT EXCHANGER					
Configuration		Two- Phase fluid 1		Two- Phase fluid 2	
Flow arrangement at nominal operating condition	Parallel flow – Both fluids flow from A to B	Nominal operating condition	Heat tranasfer from two – phase fluid 2 to two –phase fluid 1	Nominal mass flow rate (kg/s)	0.1
Cross-section are at point A1(m^2)	0.01	Nominal mass flow rate (kg/s)	0.1	Nominal inlet pressure (Mpa)	0.1
Cross-section are at point B1(m^2)	.01	Nominal inlet pressure (Mpa)	.1	Nominal inlet specific enthalpy (kJ/kg)	450
Cross-section are at point A2(m^2)	.01	Nominal inlet specific enthalpy (kJ/kg)	350	Final pressure (Mpa)	0.2
Cross-section are at point A2(m^2)	.01				

Table No.3.11 Heat Exchanger configuration

Hybrid refrigeration system is basically a combination of Refrigeration System with natural refrigerant and Solar water heating system.

In Refrigeration system fig. 3.1 , there are several components which plays a vital role in refrigeration. In figure, every components are mentioned with their name. Main components are - 1.Evaporator, 2.Compressor, 3.Condensor, 4.Expansion device. We used to calculate three points in refrigeration system , they are – 1.entry point of refrigerant in evaporator, 2.exit point of evaporator, 3.Compressor exit point. This model is completely design in Matlab simulation software. We consider different parameters through this process to find a optimum design. All values are calculated based on the three points which mentioned in methodology chapter. In this process we used natural refrigerant isobutene as a refrigerant.

In standard refrigeration system, main components specifications are already mentioned in Table No.3.1, Table No.3.2, Table No.3.3, Table No.3.4 and it is completely same as Hybrid Refrigeration system. Refrigerant mass flow rate is 0.1kg/s in evaporator, nominal enthalpy is 290 kj/kg, compressor speed is 1000 rpm and mechanical efficiency is 0.9. Nominal condensation temperature range is 303 k – 320 k, nominal evaporating temperature is 240k – 300k where as heat is transferred by cross flow from fluid A to B in evaporator and cross flow from A to B in condenser.

In Hybrid Refrigeration system, all components specification is already mentioned above except heat exchanger specification is mentioned in tabulate format in Table No.3.11 where as heat is transferred by parallel flow from solar water heating system to refrigerant at the exit point of evaporator. Here we considered mass flow rate is 0.1 kg/s, inlet pressure is 0.1 MPa. Temperature is increased by 18 degC by the help of heat exchanger.

Solar water heating system is shown in fig 3.2 where it is used as a super heater. All components are already mentioned. We are trying to design a replica of SWHS where sun is compromised as a heat source of 600 watt, solar collector tubes are compromised by a single 1.5 m tube and water tank is 1.5 m^3 volume where as initial pressure is 0.1 Mpa after that it will be 0.2 MPa, mentioned in Table No.3.5,Table No.3.6. Design in such a way that it always super heat 18 degC to the refrigerant. In this system ,sun's ray incident on the solar heating panel which is approx 600 watt after that this heat energy stored in the form of water and it is transferred in the water tank by the help of a motor.

Standard refrigeration system and Hybrid refrigeration system, all processes are taken up to 1000 sec in Matlab Simulation software to make a stable system and gets a standard data of this both system in Table No.4.1. In hybrid system there is an extra component heat exchanger is used to transfer heat.

3.6 CONCLUSION

This chapter focuses on the system's design, presenting its architecture through figures and detailing component specifications in tabulated format. The selection of parameters for the data presented in these tables is vital for achieving an optimal design within the Matlab Simulation software. The subsequent chapter will delve into the system's methodology. The figures visually depict the system's structure, aiding in understanding component interactions. Component details are organized systematically by the tabulated specifications. Parameters are meticulously chosen to gather data essential for refining design through Matlab simulations. The forthcoming chapter will elaborate on the practical approach governing the system's methodology.

CHAPTER 4

METHODOLOGY

4.1 INTRODUCTION

In this chapter we can discuss about the methodology of this hybrid refrigeration system for gaining a optimal HRS with natural refrigerant. How all the process have been done step by step we can be understand by the flow chart. The first phase of HRS designing is started with collecting metrological data where we vary the temperature of the solar water heating system to superheat the refrigerant. According to the flow chart, we first vary the temperature of the super heater, then doing simulation on matlab after that we collecting data and then we calculate the c.o.p. All of the processes are used to design a optimal HRS cost effective system to the consumer and also concern about the ODP, GWP, Environmental impact. In this chapter, all load are calculated like refrigeration effect, solar water heating effect, the compression effect and also c.o.p of the system. How it is useful for our society, it can be justified in this project and also how this system gives benefit to the consumer by saving their money.

4.2 FLOW CHART TO SHOW OPTIMAL DESIGN METHODS

There are various steps have been done to achieve a optimal hybrid refrigeration system. We can understand this project thorough the steps one by one from this fig.4.1. Basically there are five parts –

1. Refrigeration system

2. Solar heating system

3. Combined two system to make a HRS

4. Matlab simulation

5. Calculation.

6. Result

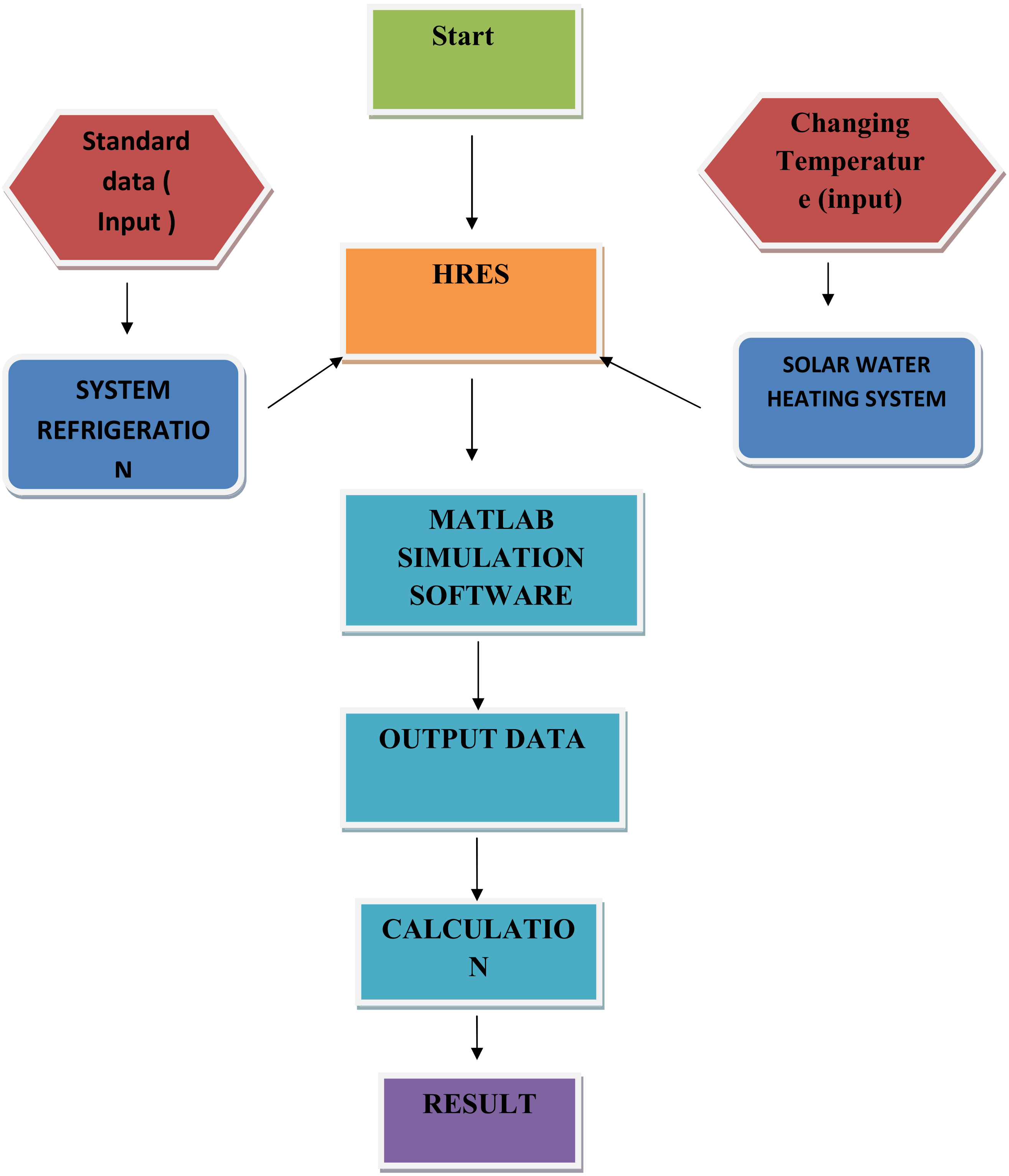

Fig.4.1 Flow chart of optimal design

4.3 DATA SHEET

In this chapter different parameters are considered ,they are temperature, pressure, enthalpy and their units are respectively degC, bar, kJ/kg.

4.3.1 Hybrid Refrigeration System (HRS)

This data sheet of HRS can be found by considering the following data where mass flow rate of refrigerant 0.1 kg /s, nominal evaporating range is 240 k – 300 k, nominal condensing temperature is 303 k – 320 k, inlet enthalpy is 290 kJ / kg and compressor speed is 1000 rpm where we maintain 0.1 bar – 0.4 bar pressure range. Specification of all the components of this Hybrid Refrigeration system is mentioned in tabulate format in chapter 3. Varying this parameters, we get the optimal design data through matlab simulation software which is mentioned in row no.5 in table no.4.1.

NO.	PROPERTIES	EVAPORATION INLET	EVAPORATOR OUTLET	SOLAR WATER HEATER OUTLET	COMPRESSOR OUTLET	C.O.P 1 (with superheating)	C.O.P 2 (without superheating)
1.	TEMPERATURE	-15.08	-7.01	16.25	86.48	2.321	1.766
	PRESSURE	0.0888	0.0888	0.0888	.4096		
	ENTHALPY	271	546.8	584.1	702.9		
2.	TEMPERATURE	-14.14	-6.293	16.35	85.1	2.38	1.815
	PRESSURE	0.09229	0.09229	0.09229	.4069		
	ENTHALPY	271.3	547.8	584.1	700.1		
3	TEMPERATURE	-13.05	-5.45	16.48	86.5		
	PRESSURE	0.09632	0.09632	0.09635	.4251		

	ENTHALPY	271.5	548.8	584	702.7	2.336	1.8018
4.	TEMPERATURE	-11.78	-4.395	16.6	82.3	2.523	1.93
	PRESSURE	0.1013	0.1013	0.1013	0.4072		
	ENTHALPY	271.7	550.3	584.1	694.5		
5.	TEMPERATURE	-10.36	-3.256	16.75	81.86	2.557	1.97
	PRESSURE	0.107	0.107	0.107	0.4147		
	ENTHALPY	271.9	551.7	584.1	693.5		
6.	TEMPERATURE	-8.501	-1.728	16.94	79.56	2.689	2.08
	PRESSURE	0.115	0.115	0.115	0.4189		
	ENTHALPY	272.2	553.8	584.2	688.9		
7.	TEMPERATURE	-6.81	-0.3081	17.17	75.96	2.90	2.243
	PRESSURE	0.1225	0.1225	0.1225	.4092		
	ENTHALPY	272.2	555.6	584.2	681.9		
8.	TEMPERATURE	-4.824	1.346	17.42	73.12	3.10	2.413
	PRESSURE	0.132	0.132	0.132	0.4125		
	ENTHALPY	272.4	557.9	584.3	676.2		
9.	TEMPERATURE	-2.882	3.034	17.73	73.91	3.107	2.464
	PRESSURE	0.1417	0.1417	0.1417	0.4394		
	ENTHALPY	272.4	560.2	584.4	677		
10.	TEMPERATURE	-0.8061	4.77	18.02	67.33	3.60	2.83
	PRESSURE	0.1526	0.1526	0.1526	0.4147		
	ENTHALPY	272.5	562.4	584.4	664.8		
11.	TEMPERATURE	1.128	6.514	18.37	63.94	3.96	3.13
	PRESSURE	0.1636	0.1636	0.1636	0.4109		
	ENTHALPY	272.5	564.9	584.6	658.3		

12.	TEMPERATURE	3.191	8.252	18.71	64.51	3.97	3.218
	PRESSURE	0.1755	0.1755	0.1755	0.4391		
	ENTHALPY	272.6	567.1	584.6	658.6		
13.	TEMPERATURE	5.271	10.16	19.09	57.59	4.83	3.887
	PRESSURE	0.1887	0.1887	0.1887	0.4114		
	ENTHALPY	272.7	569.7	584.7	646.1		

Table No.4.1 Data sheet of the hybrid refrigeration system

4.3.2 Hybrid refrigeration system (Enthalpy)

In this table we are separating the enthalpy values from the HRS data table (table no.4.1) for better understanding and doing calculation in a proper way.

No.	Properties	EVAPORATION INLET	EVAPORATOR OUTLET	SOLAR WATER HEATER OUTLET	COMPRESSOR OUTLET
1.	Enthalpy (kJ/kg)	271	546.8	584.1	702.9
2.		271.3	547.8	584.1	702.9
3.		271.5	548.8	584	702.7
4.		271.7	550.3	584.1	694.5
5.		271.9	551.7	584.1	693.5
6.		272.2	553.8	584.2	688.9

7.		272.2	555.6	584.2	681.9
8.		272.4	557.9	584.3	676.2
9.		272.4	560.2	584.4	677
10.		272.5	562.4	584.4	664.8
11.		272.5	564.9	584.6	658.3
12.		272.6	567.1	584.6	658.6
13.		272.7	569.7	584.7	646.1

Table No.4.2 Data sheet of the hybrid refrigeration system of Enthalpy

4.3.3 Data of Normal Refrigeration System (NRS)

This data sheet of NRS can be found by considering the following data where mass flow rate of refrigerant 0.1 kg /s, nominal evaporating range is 240k, nominal condensing temperature is 320 k , inlet enthalpy is 290 kJ / kg and compressor speed is 1000 rpm where we maintain 0.1 bar – 0.4 bar pressure range. Specification of all the components of this normal Refrigeration system is mentioned in tabulate format in chapter 3.

Properties	Evaporator inlet	Evaporator outlet	COMPRESSOR OUTLET	C.O.P
TEMPERATURE	-10	-2	73	2.35
PRESSURE	.108	.1084	.404	
ENTHALPY	266.3	553.5	675.7	

Table No.4.3 Data of Normal Refrigeration System

4.3.4 Optimal Hybrid Refrigeration System

This is a optimal design data which is collected from the table no.4.1.This data sheet of HRS can be found by considering the following data where mass flow rate of refrigerant 0.1 kg /s, nominal evaporating range is 220k, nominal condensing temperature is 315 k , inlet enthalpy is 290 kJ / kg and compressor speed is 1000 rpm where we maintain 0.1 bar – 0.4 bar pressure range. Specification of all the components of this hybrid refrigeration system is mentioned in tabulate format in chapter 3.

Properties	Evaporator inlet	Evaporator outlet	Solar Water Heater Outlet	Compressor Outlet	c.o.p 1 (super heating)	c.o.p 2 (without super heating)
TEMPERATURE	-10.36	-3.256	16.75	81.86		
PRESSURE	0.107	0.107	0.107	0.4147	2.557	1.97
ENTHALPY	271.9	551.7	584.1	693.5		

Table No. 4.4 Optima Hybrid System

4.4 CALCULATION

There are few properties are required to calculate for determining a system is optimal design or not, they are -

1. The pressure ratio = Compressor Output pressure / Compressor Input pressure
2. The Isentropic Compression work, W comp (kJ/Kg) = Compressor outlet enthalpy – Compressor inlet enthalpy
3. The refrigerating effect (RE) (kJ/Kg) = Evaporation outlet enthalpy - Evaporation inlet enthalpy
4. The power per ton of refrigeration (P/TR) (kW) = 3.5 W comp/ RE (4)
5. The coefficient of performance (COP) = RE / W comp

All the calculation is done based on the data sheet which is mentioned in table no.4.3 and table no.4.4.

We calculate refrigeration effect or load of the hybrid refrigeration system.

Refrigeration effect = (Evaporation outlet enthalpy - Evaporation inlet enthalpy) kj/kg

= 551.7 – 271.9 kj/kg

= 279.8 kj/kg

And now we calculate refrigeration effect or load of the normal refrigeration system.

Refrigeration effect = (Evaporation outlet enthalpy - Evaporation inlet enthalpy) kj/kg

= 553.5 – 266.3 kj/kg

= 287.2 kJ/kg

If we compare the above refrigeration effect of the NRS and the HRS, then we see that normal system refrigeration effect is better.

Now we calculate Compression work of the hybrid system.

Compression work = (Compressor outlet enthalpy – Compressor inlet enthalpy) kj/kg

= 693.5 - 584.1 kJ/kg

= 109.4 kJ/kg

Now we calculate of the normal refrigeration system compression work.

Compression work = (Compressor outlet enthalpy – Compressor inlet enthalpy) kj/kg

= 675.7 -553.5 kJ/kg.

= 122.2 kJ/kg.

Now we can see that compression work of hybrid system is less than the general refrigeration system.

This is happened only because of the help of Solar water heating system which reduce the compression work. So **now we calculate how much solar heating is done on the hybride system**.

Solar heating system load = (Compressor inlet enthalpy – Evaporation outlet enthalpy) kj/kg

= 584.1 - 551.7 kJ/kg

= 32.4 kJ/kg

So solar water heating system reduces the compression work by 32.4 kJ/kg, which will help the hybrid system to increase the c.o.p of the system.

C.O.P -

C.O.P is the coefficient of performance which is defined as the ratio of refrigeration effect and the compressor work done. Higher COPs equate to higher efficiency, lower energy (power) consumption and thus lower operating costs.

C.O.P = Refrigeration effect / Compressor work done

Calculation of the C.O.P of the normal refrigeration system.

C.O.P = Refrigeration effect / compression work done or load

= 287.2 kj/kg / 122.2 kj/kg.

= 2.35

Calculation of C.O.P of the hybrid refrigeration system.

C.O.P = Refrigeration effect / compression work done or load

= 279.8 kj/kg / 109.4 kj/kg

= 2.557

Percentage of C.O.P is increasing = (2.557-2.35)/2.557

= 0.0809

= 8.09 %

C.O.P of the system is defined by coefficient of the performance of the system. .C.O.P is directly proportional to the uses cost, if c.o.p is increasing then uses money is decreasing and if c.o.p is decreasing then consumer money will be increasing.

According to the c.o.p we understand that solar heating system is beneficial for the consumer.

In refrigeration system compressor work is a important criteria to compare the input power of hybrid system and normal refrigeration system. So we calculate power input per ton of refrigeration between Hybrid refrigeration system and Normal Refrigeration system.

TR -

This term is used in refrigeration system.TR full form is Ton of Refrigeration. A ton of refrigeration, also called a refrigeration ton, is a unit of power where we calculate that how much heat is extracted from 1000 kg of water at 0 degree centigrade to convert into 0 degree ice in 24 hours.

Latent heat of ice = 335 KJ/Kg

1 TR= 1000*335 KJ in 24 hours

= (1000*335) /(24*60)

= 232.6 KJ/min

= 3.5 KJ/ sec

Calculation of power input in the Normal Refrigeration System is -

The power per ton of refrigeration (P/TR) (kW) = 3.5 Wcomp/ RE

= 3.5 *122.2 /287.2

= 1.489 kW

=1489 watt

Calculation of power input in the Hybrid Refrigeration System is –

The power per ton of refrigeration (P/TR) (kW) = 3.5 W comp / RE

= 3.5*109.4 / 279.8

= 1.368 kW

= 1368 watt

Compressor work saves per TR is (kW) = (1.489 – 1.368) kW

= .121 kW per TR.

= 121 watt

24 hours Hybrid system saves power input = 121 watt

Then , 365 days Hybrid system saves power input = 121 * 365

= 44,165 watt.

In Hybrid system, power input saves = (121 / 1368) per TR.

= 0.08845 per TR.

CHAPTER 5

RESULT AND DISCUSSION

5.1 INTRODUCTION

In this chapter we discuss about the result of this project based on data sheet and calculation which is already mentioned above chapters. There are various types of graphs present in this chapter for better understanding of the refrigerant behavior. Varying different parameters in matlab simulation to find a optimal design. Here comparison of hybrid refrigeration system and normal refrigeration system is discussed. Here we used isobutene (r600a) as a natural refrigerant where no pollution is there and there is no global warming effect.

5.2 OPTIMUM HYBRID REFRIGERATION SYSTEM

This table is found by the help of data sheet in table no.4.1 where all simulation data is mentioned. This is a optimum design data sheet which helps to get a design of maximum c.o.p model.

Properties	Evaporator inlet	Evaporator outlet	Solar Water Heater Outlet	Compressor Outlet	c.o.p 1 (super heating)	c.o.p 2 (without super heating)
TEMPERATURE	-10.36	-3.256	16.75	81.86	2.557	1.97
PRESSURE	0.107	0.107	0.107	0.4147		
ENTHALPY	271.9	551.7	584.1	693.5		

Table No. 5.1 Optimum Refrigeration Hybrid System

5.3 NORMAL REFRIGERATION SYSTEM (STANDARD)

This is the standard data sheet of natural refrigerant (Isobutane) based vapour compression refrigeration system where it provides maximum c.o.p at corresponding temperature and pressure.

Properties	Evaporator inlet	Evaporator outlet	COMPRESSOR OUTLET	C.O.P
TEMPERATURE	-10	-2	73	2.35
PRESSURE	.108	.1084	.404	
ENTHALPY	266.3	553.5	675.7	

Table No.5.2 Normal Refrigeration System

5.4 COMPARISON BETWEEN HYBRID REFRIGERATION SYSTEM AND NORMAL REFRIGERATION SYSTEM

Here we compare the HRS and NRS by different parameters which is mentioned in table no.5.3. Each and every criteria HRS is getting better result than NRS except pressure ratio.Their is little drop in pressure ration in HRS. Further comparison is mentioned below.

Refrigeration system	Pressure ratio	Refrigeration effect (kJ/kg)	Compressor work (kJ/kg)	C.O.P	Power per TR (kW/ TR)
HRS	3.875	279.8	109.4	2.557	1.368
NRS	3.74	287.2	122.2	2.35	1.489

Table No.5.3 Comparison between Hybrid refrigeration system and Normal refrigeration system

5.5 SOLAR WATER HEATING SYSTEM

Specification is already mentioned in table no.3.6 in chapter 3.Here we are trying to execute the actual data table of SWHS, how it responds when heat is transferred from SWHS to HRS, what are the changes happened, all are mentioned in table no.5.4.

Incident radiation (watt)	Pressure in Water Tank (bar)	Temperature in Water Tank (degree centigrade)	Temperature after super heating (degree centigrade)	Pressure after super heating (bar)
600	.2	60	45	.2

Table No. 5.4 Solar Water Heating System

5.6 COMPARISON OF CHARACTERISTICS OF HYBRID REFRIGERATION SYSTEM AND NORMAL REFRIGERATION SYSTEM

All the simulations are done in matlab simulation software considering the parameters and conditions. As a result those graphs are generated in matlab simulation software. This graphs are used to understand the behavior of refrigerant how it reacts with changing the parameters value.

Pressure graph

In pressure graph fig.5.1 shows the variation in pressure of a HRS and fig.5.2 shows the variation in pressure of a NRS. If we look properly then we find that the pressure range is between 1 bar to 4.2 bar for both system. Initially the pressure is 1 bar at evaporator site, after compression by the compressor pressure reaches to 4.2 bar. In HRS the pressure line at evaporator site is suddenly increase then after sometime it will reach at uniform line. This is happened due to the super heating by the SWHS. But in NRS, the pressure is uniform at evaporator site, there is no pressure increment is happened.

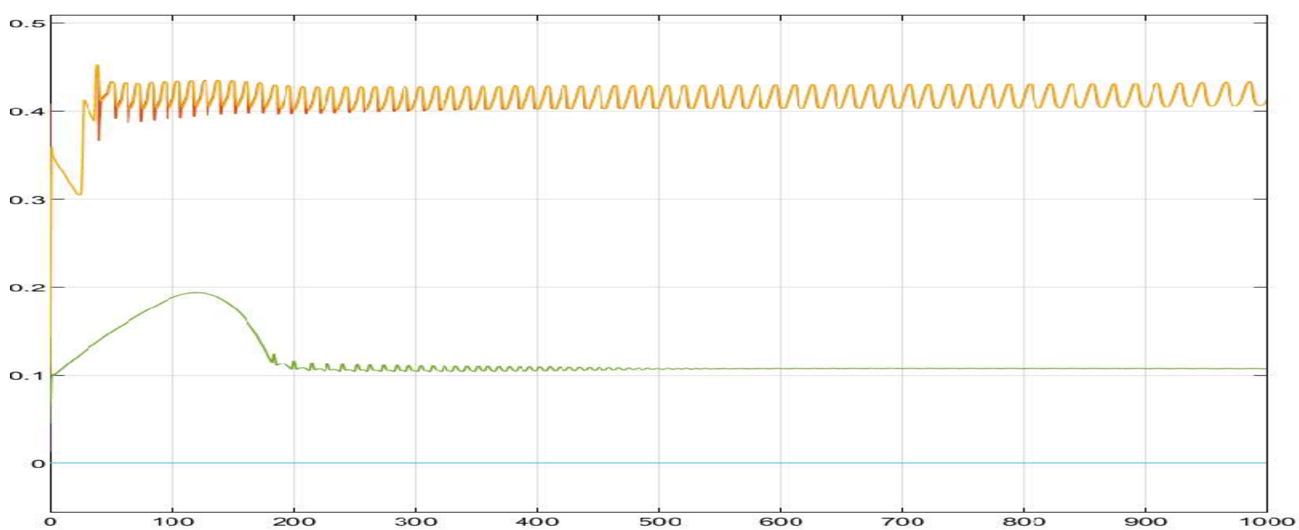

Fig.5.1 Variation in pressure at evaporator and condenser site in HRS

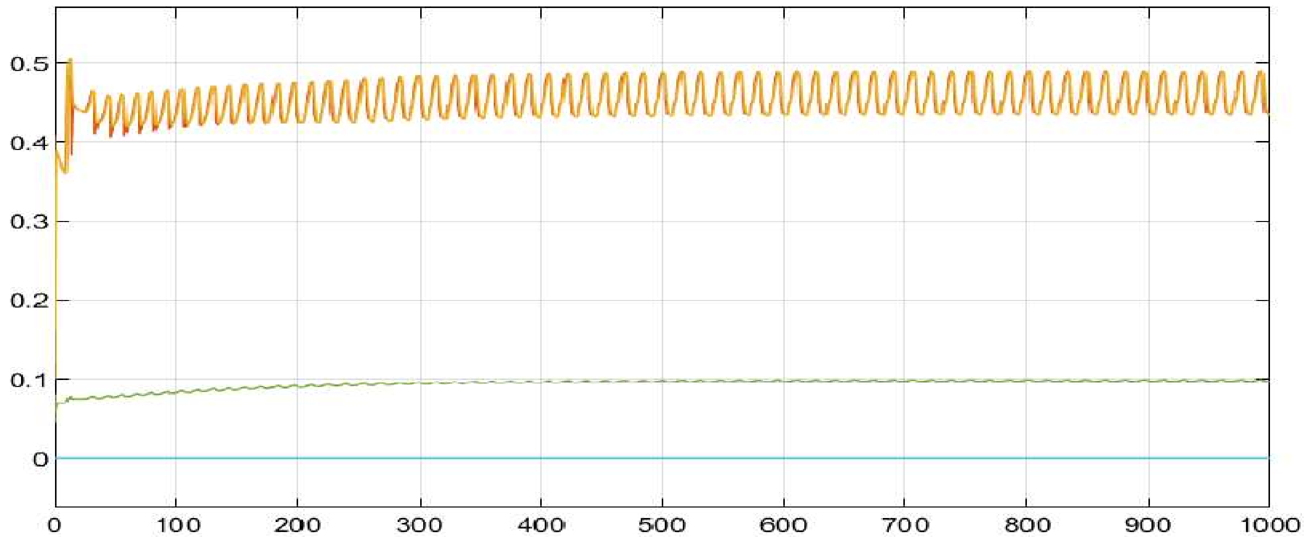

Fig. 5.2 Variation in pressure at evaporator and condenser site in NRS

Temperature graph

In temperature graph fig.5.3 shows the varition in temperature of HRS and fig.5.4 shows the variation in temperature of NRS. There are four temperature lines are available in each graph. They shows different temperature value at different location of a refrigeration system. There is one temperature line is very iportant in both system and it is specified by blue colour. This blue colour line is coming from evaporator exit point at -3 degC for both the system but in HRS it will jump suddenly at 16 degC. This is happaned due to the super heating by the SWHS at the exit point of the evaporator in HRS and then the blue temperature line is maintained this temperature at uiform rate. But in NRS there is no sudden jump in temperature,it is maintaintaing its temperature at -3 degC from evaporator exit point to compressor inlet pont.

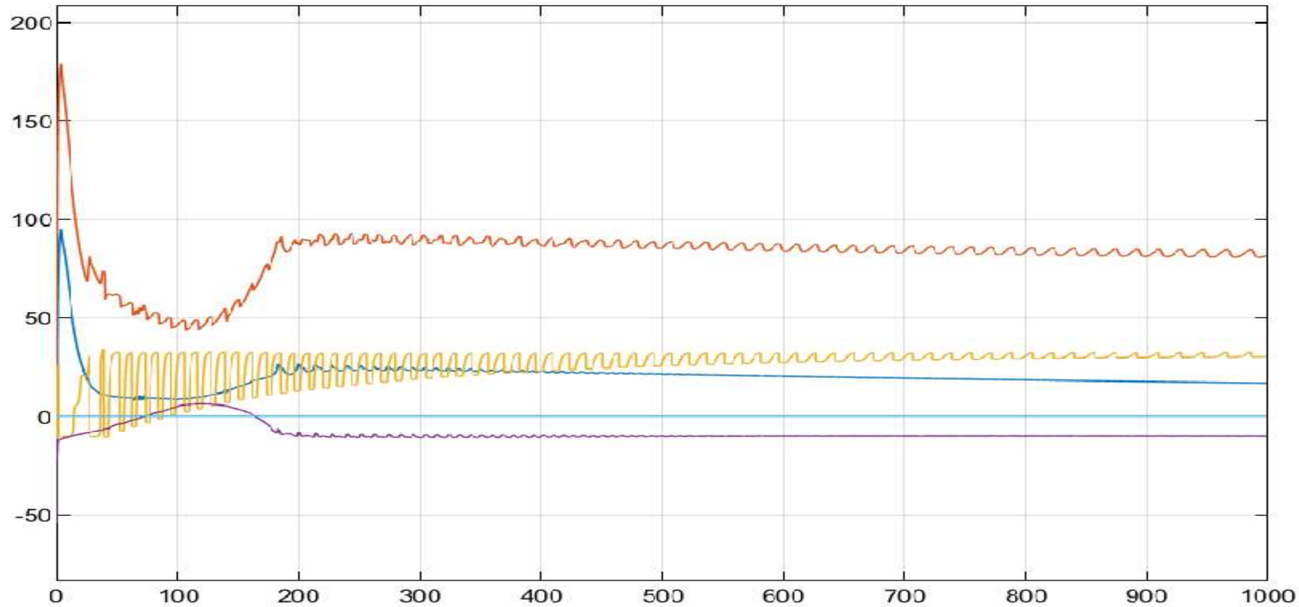

Fig. 5.3 Variation in Temperature in HRS

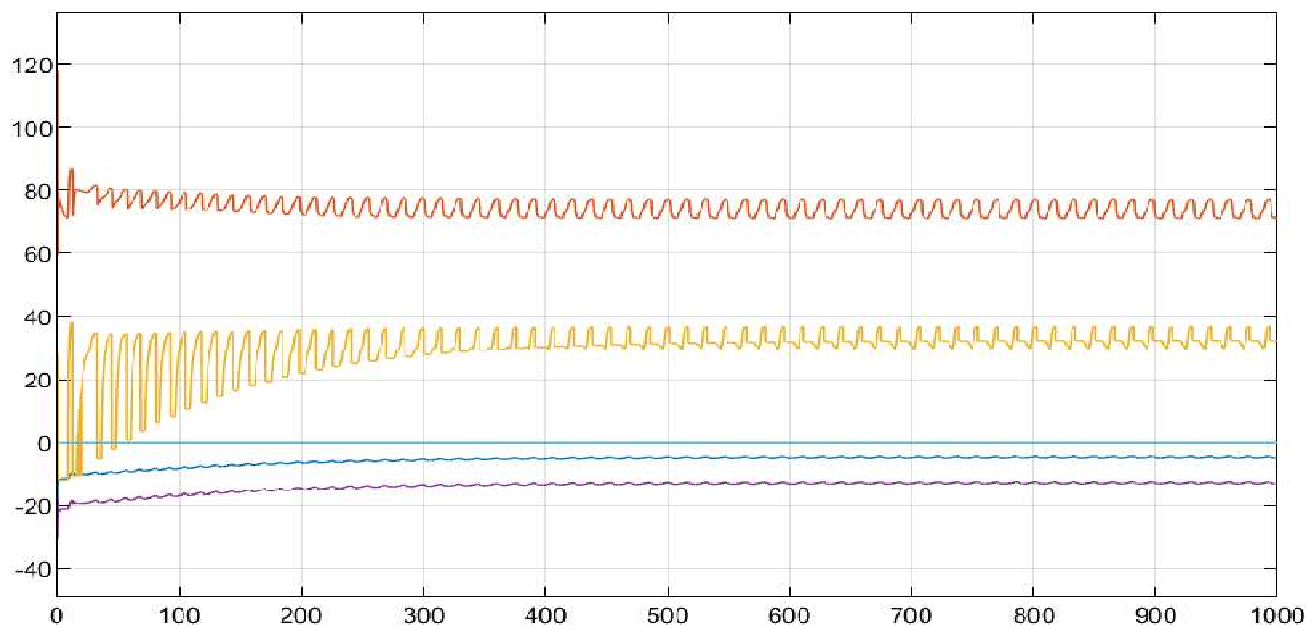

Fig.5.4 Variation in Temperature in NRS

Enthalpy graph

If we observe enthalpy graph fig.5.5 shows Variation in Enthalpy of a HRS and fig.5.6 shows the variation in enthalpy of a NRS. Enthalpy is a function of temperature only, so if temperature is increasing or decreasing then enthalpy also increase and decrease respectively. In HRS,the enthalpy lines are first decrease then increase. This is happened due to the super heating by SWHS. But in NRS there is no deflection in enthalpy lines because there is no super heating is done.

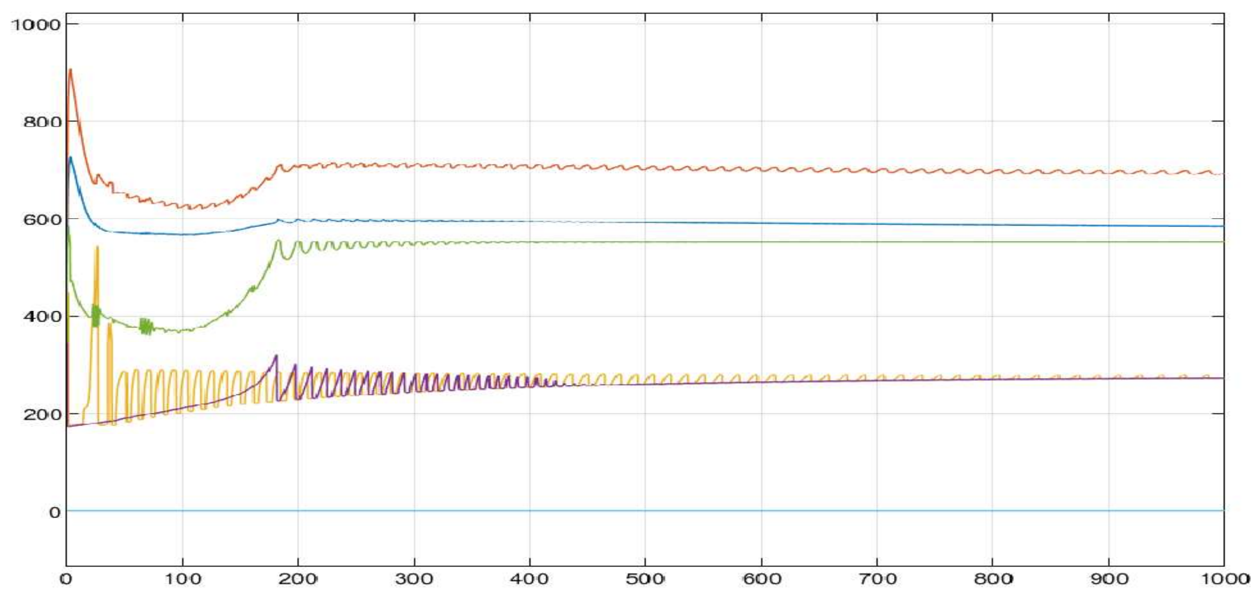

Fig.5.5 Variation in Enthalpy in Hybrid refrigeration system

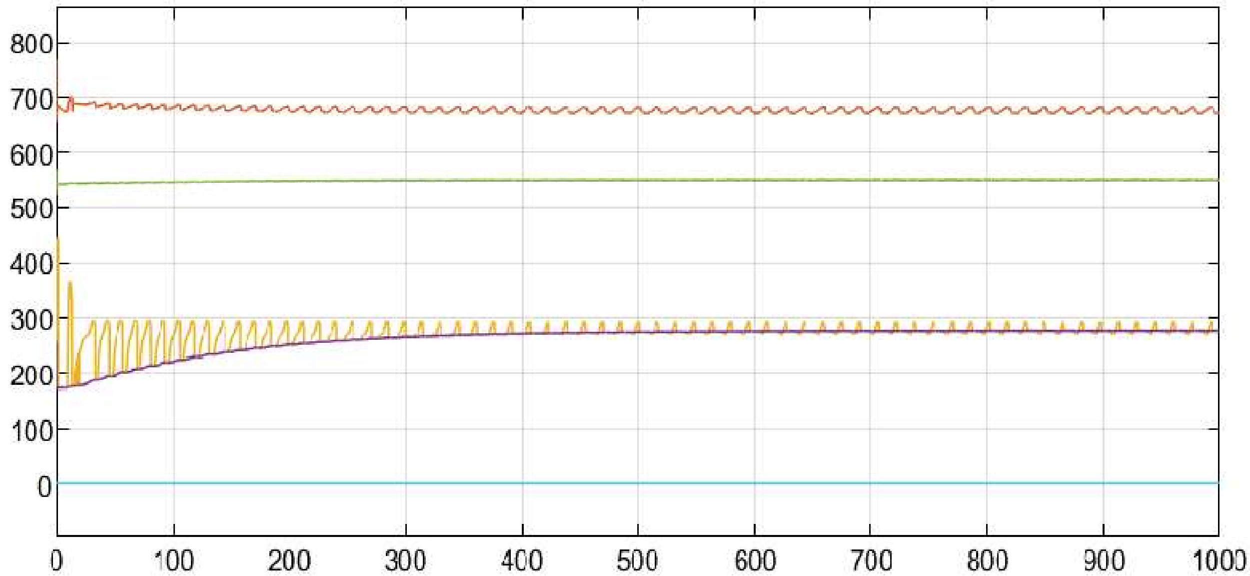

Fig. 5.6 Variation in Enthalpy in Normal refrigeration system

Pressure-Enthalpy graph

In pressure enthalpy graph fig.5.7 shows the behavior of refrigerant in a hybrid system under superheating condition and fig.5.8 shows the behavior of refrigerant in a NRS with out super heating system. we are basically plotting the behavior of iso-butane refrigerant. If we are comparing both the diagram then we will see that the diagram almost same by their value which is mentioned in table no,5.1, and table no. 5.2 except the value at evaporator exit site to compressor inlet site. In HRS, due to super heating by the SWHS there is a increment in temperature, due to increment in temperature there is increase in enthalpy. So we get a small reduction in compressor work in HRS. But in NRS there is no super heating is done so it will behave as a traditional refrigerant in p-h diagram.

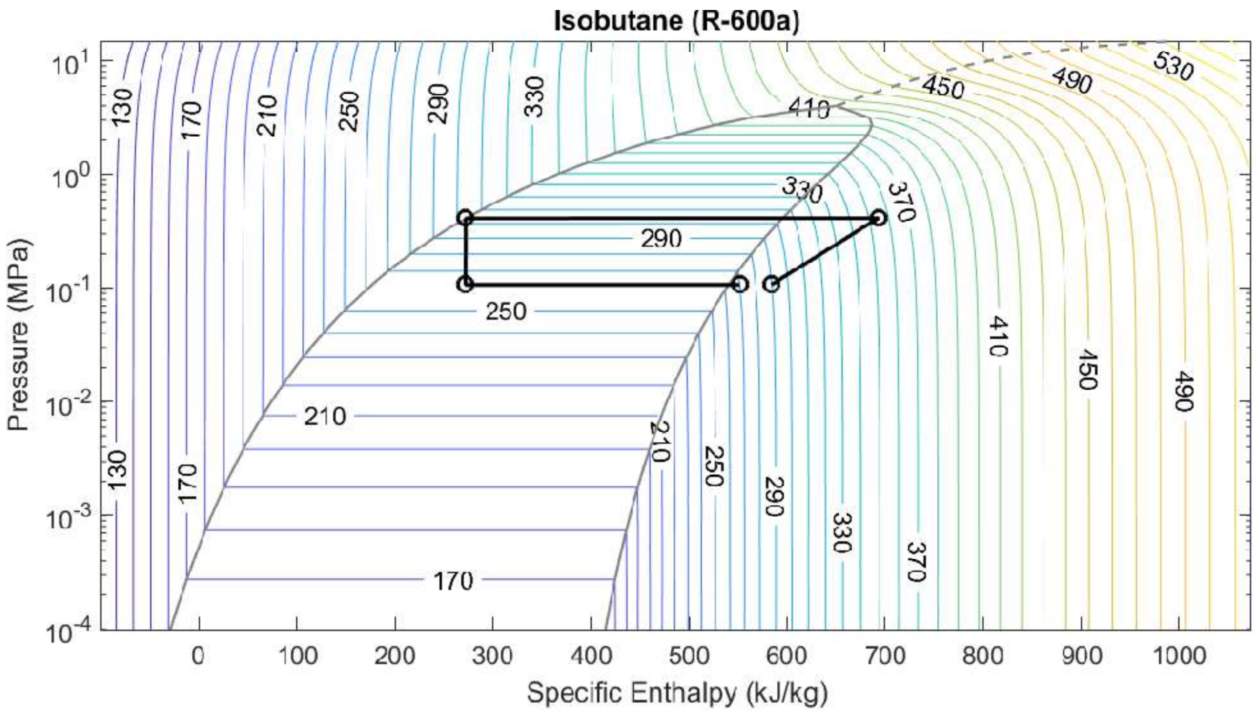

Fig. 5.7 P-H diagram of the Hybrid refrigeration system under Superheating condition

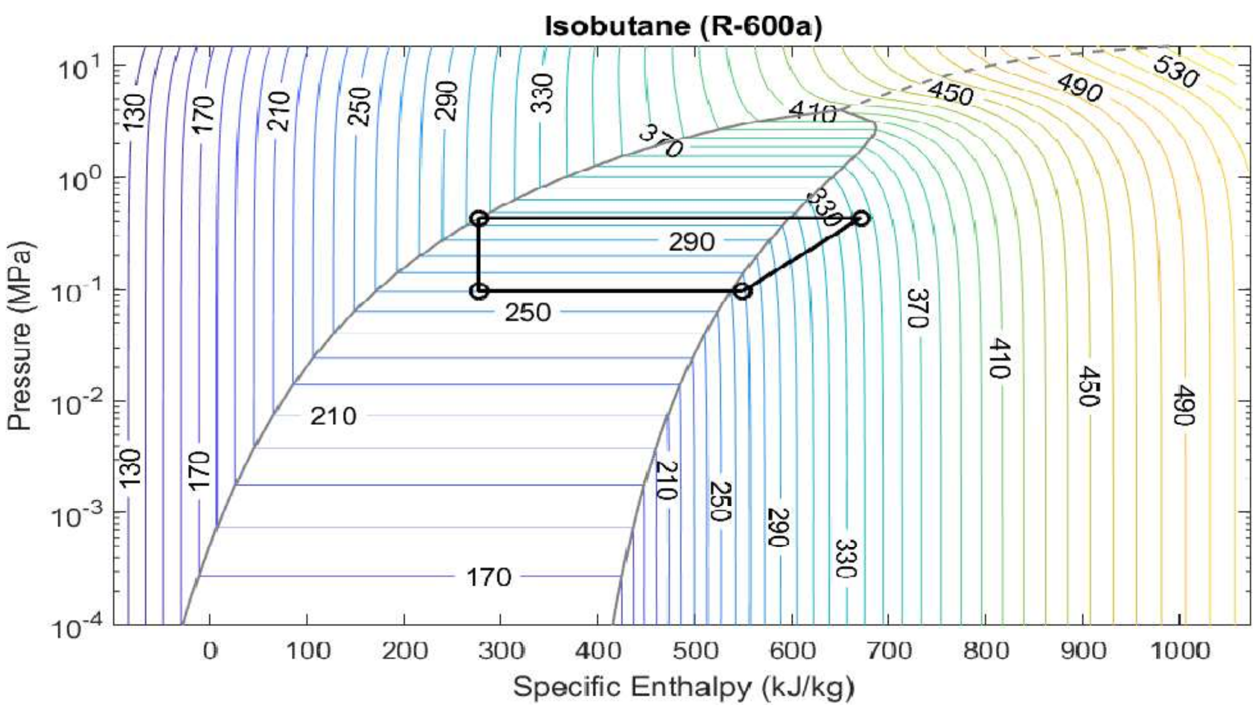

Fig. 5.8 P-H diagram of the Normal refrigeration system without Superheating condition

C.O.P compression

In this diagram, cop 1 is depicted the performance of a HRS with super heating and cop 2 is depicted the performance of HRS without super heating condition. C.O.P comparison is one of the main criteria in refrigeration system to find out the optimum design among the all designs. We all know that c.o.p is directly proportional to the consumer daily cost. If cop is more than the this system performance is better and it will consume less electricity and save consumer money. So, here we plot c.o.p 1, c.o.p 2 in a single graph to compare the performance of both the system.. In this graph, we see that cop 1 is always has greater value than cop2. This is happened due to the super heating in cop 1 refrigeration system. So, we say that cop 1 is better than cop2.

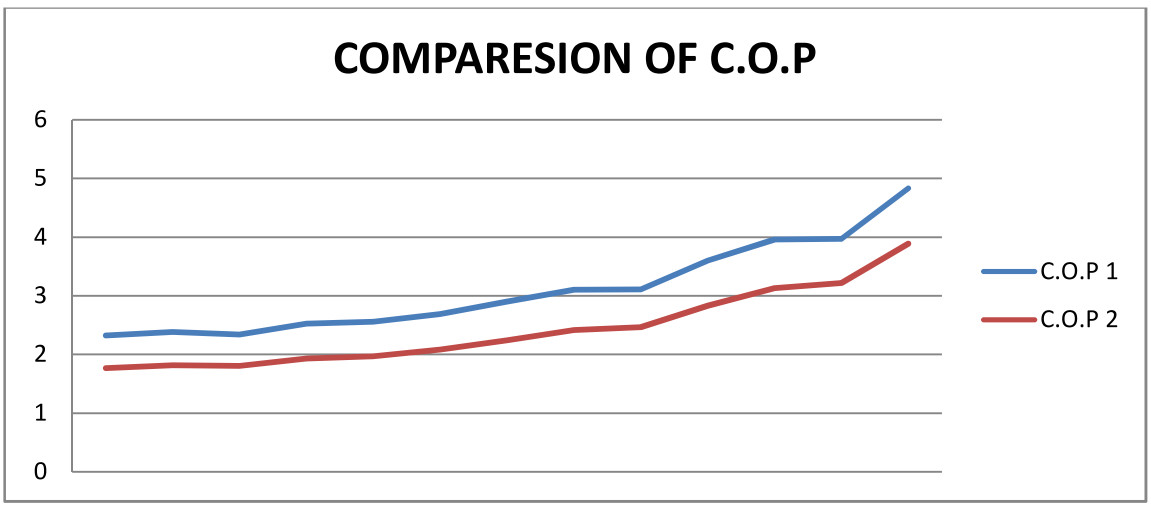

Fig.5.9 Comparison between c.o.p 1 and c.o.p 2.

5.7 CHARACTERISTICS OF SOLAR WATER HEATING SYSTEM

All data and specification of SWHS is already mentioned above. Due to this data, we get different types of graph of SWHS through the matlab simulation. This graphs shows the behavior of water according to the temperature and pressure**.**

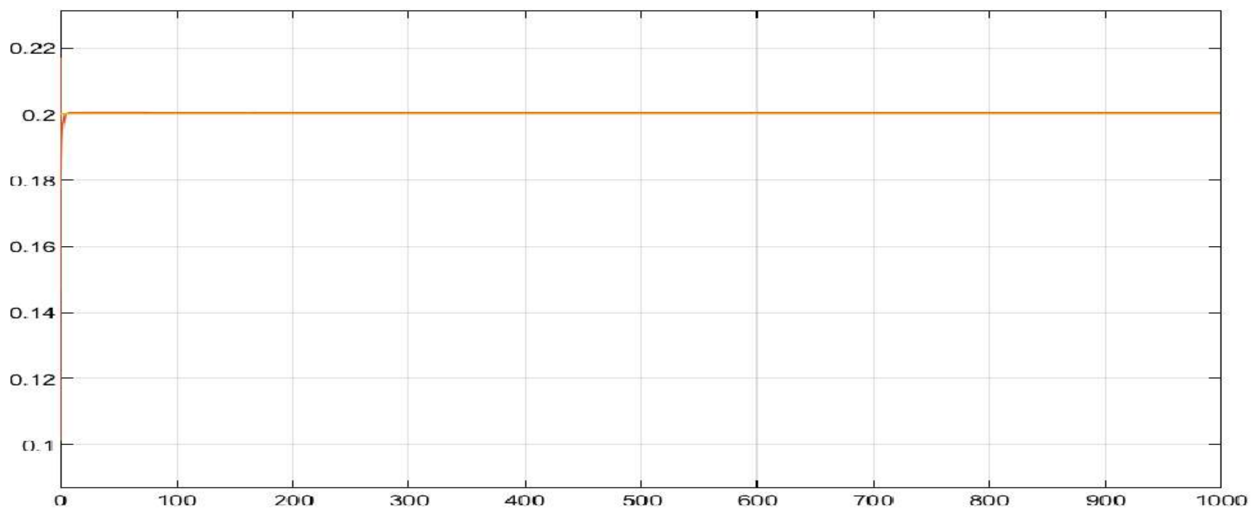

Fig.5.10 Variation in Pressure

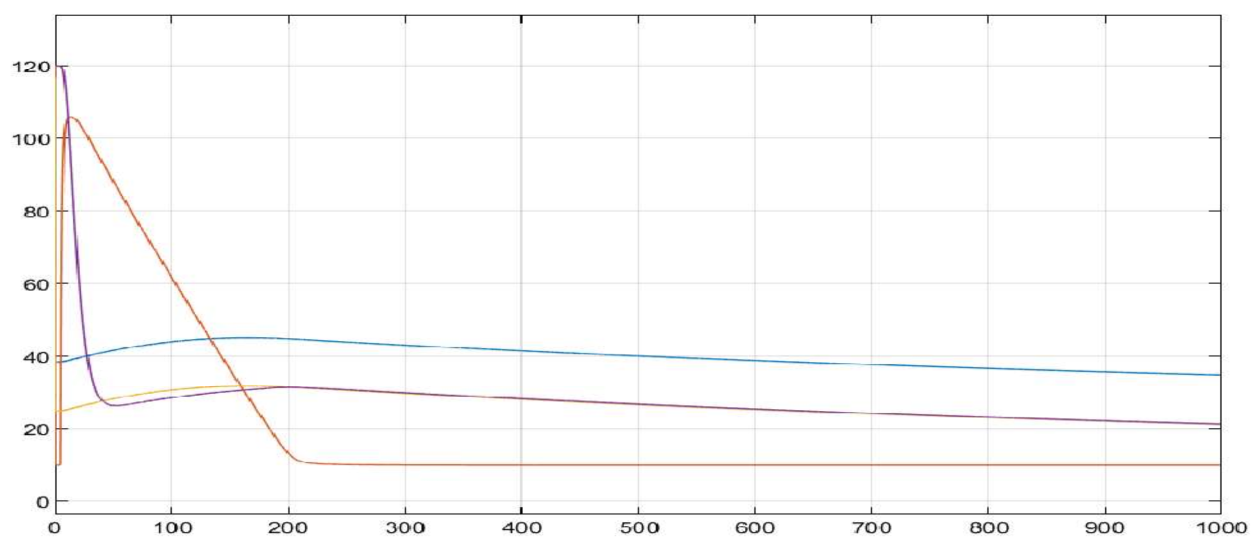

Fig. 5.11 Variation in Temperature

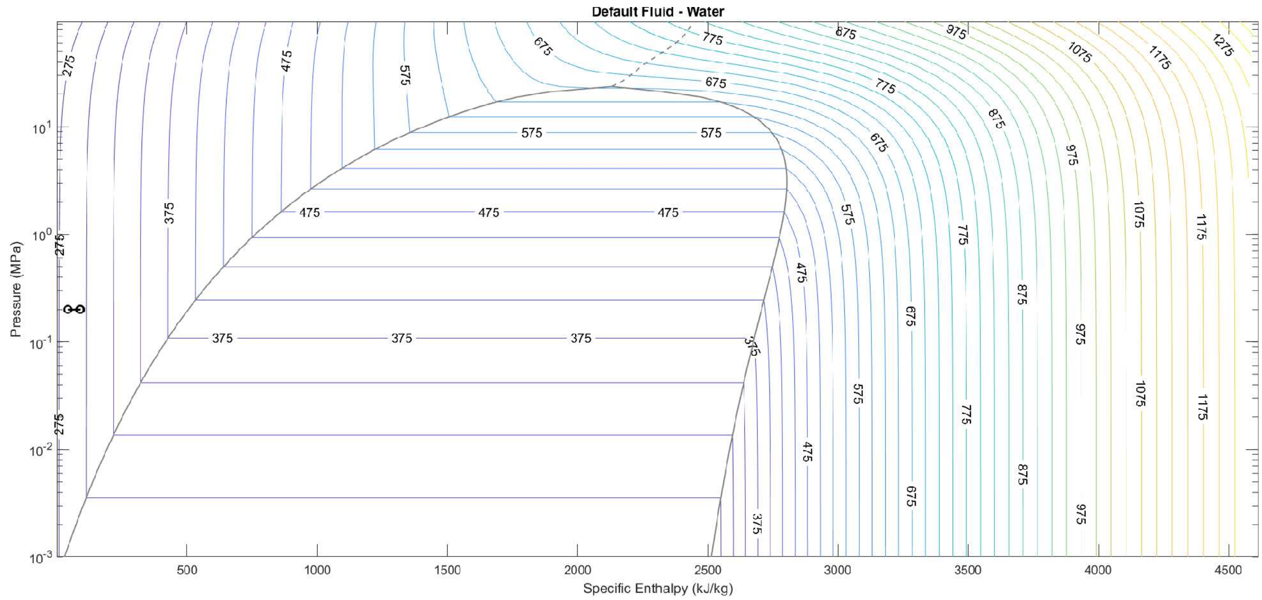

Fig.5.12 P-H diagram of Solar Water Heating System

Different types of graphs are found in characteristics of SWHS. In pressure graph fig.5.10, we see that initially the pressure is 1 bar after that due to this heat addition by the water, pressure is increasing up to 2 bar and then the pressure will be constant. In temperature graph fig5.11, we see different lines of temperature, they are basically different point of SWHS. We also consider p-h graph where it is denoted by a straight line because there is temperature and pressure is increasing and no phase is changing shown in fig.5.12.

5.8 CONCLUSION

In this chapter, all the analysis is done based on the data shown in the table format in the optimal Hybrid refrigeration system. Varying the temperature, pressure and other parameters in a matlab simulation software, to get a optimal design, considering with natural refrigerant and the environment impact.

According to the data sheet analysis and the calculation, we conclude that as follows-

1. We get a optimal HRS where c.o.p is now 2.557 from 2.35 of NRS by the help of super heating the HRS 18 degC shown in table no.5.1.

2. There is a 8.09% increment in c.o.p. by help of SWHS.

3. Their is also increase in refrigeration effect of 7.9 kJ/kg.

4. By the help of super heating there is seen in reduction of compressor work of 11.8 kJ/kg.

5. By super heating SWHS will increase enthalpy by 32.4 kJ/kg ,we can see this in calculation part in chapter 4.

6. If we compare data of HRS and NRS shown in table no.5.3 ,we find that power per TR of HRS is 1.368 which is less than NRS of 1.489. It means HRS required less compressor work for 1 ton of refrigeration compare to the NRS.

7. There is a drop in pressure ration of HRS of 3.74 from a NRS 3.875,shown in table no.5.3.

8. If we consider the same system with out super heating and with super heating ,then c.o.p of the super heating system will be 2.557 and with out super heating system is 1.97 which is shown in table no.4.4

9. There is also a good thermodynamic property of natural refrigerant isobutene shown in table no.1.3.Their is also no GWP and ODP show in table no.1.1.

If we are trying to superheat the refrigeration system and use natural refrigerant then it(HRS) provides a lots of benefit to the society and environment. In the next chapter we discuss the conclusion and future scope of this thesis is described in detail.

CHAPTER 6

CONCLUSION, FUTURE SCOPE AND LIMITATIONS

6.1 CONCLUSION

This thesis introduces an optimal design and assessment of standalone hybrid refrigeration system for house hold uses. Initially we studied so many journals on refrigeration system, solar thermal system and natural refrigerant based system. We also study of hybrid system where multiple systems are used to make a hybrid system for better performance, all of this related journals are already mentioned in summary in review chapter. In this thesis, we first understand carefully about the working process of refrigeration system and also working condition where it provides the maximum c.o.p at corresponding temperature and pressure. Then we get knowledge on solar water heating system and try to understand the working procedure. Here we took natural refrigerant isobutane (R600a) as a refrigerant. First we design refrigeration system with natural refrigerant in matlab software with a standard configuration. Then we design separately solar water heating system in matlab with a standard configuration. Then we combined both the system in matlab simulation software to make a hybrid refrigeration system at a standard specification and parameter which is mentioned in chapter…...This combination is used to simulate in Matlab simulation software for getting a optimal design of hybrid refrigeration system. Due to this optimal design of HRS, there is a reduction of compressor work compare to the standard refrigeration system, so that reason we get a maximum c.o.p system at corresponding temperature and pressure which helps to reduce the consumer daily cost of refrigeration.

The major steps of the present work are summarized as follows-

1. We review all related journals.
2. Design a 1 Ton refrigerantion system with natural refrigerant Isobutane(R600a) at a standard configuration in matlab.
3. Then design a solar water heating system separately in matlab.
4. Then combined both the system and make a hybrid system.
5. Due to this simulation, a lots of data is generated, is mentioned in methodology chapter.
6. Based on the data sheet, all calculation is done.
7. Result and calculated value is mentioned in chapter 5.

The major results of the present work are summarized as follows-

1. Solar water heating system is used to super heat the refrigeration by 18 degC.

2. Due to super heating, there is reduction of compressor work by 11.8 kJ/kg, increment of enthalpy by 32.4 kJ/kg and increment of refrigeration effect by 7.9 kJ/kg.

3. There is a increment of c.o.p 2.35 of normal refrigeration system to c.o.p 2.557 of hybrid refrigeration system.

4. There is a 8.09 % increment in c.o.p by the help of SWHS.

The major pro and cons of the present work are summarized as follows

1. The optimal design of HRS gives a better c.o.p then a traditional design which helps to save a lot of money of the consumer.

3. It requires a high initial investment because here we installed a combined system.

4. It provides multipurpose application, like- SWHS is used in home uses as well as HRS is used in refrigeration effect.

5. This type of systems are useful for Hospitals, Hotels, Industries etc.

This system is practically possible for the society, so we design a prototype in matlab in such a way that it provides theoretical as well as practical possibilities. Its investment is high initially but there will be no expenses further. Here solar water heating system is also used for multipurpose application. There is used natural refrigerant, so no pollution and global warming is happened.

6.2 FUTURE SCOPE

The future of refrigeration is expected to be more energy efficient and sustainable. This is due to a growing awareness of the environmental impact of these technologies, as well as advances in materials and technologies that allow for more efficient cooling systems. Additionally, there is a growing trend towards using natural refrigerants, such as isobutane (R600a) which are less harmful to the environment than traditional refrigerants.

Certainly, Here are some key aspects of the future of refrigeration system:

1. Energy Efficiency: Energy efficiency will be a primary focus in the future of cooling technologies. Manufacturers are investing in research and development to create more energy-efficient systems that minimize power consumption and reduce greenhouse gas emissions. This includes improving the efficiency of compressors, heat exchangers, and overall system design.
2. Sustainable Refrigerants: The phase-out of hydro fluorocarbons (HFCs), which have a high global warming potential, is gaining momentum. The future of refrigeration and air conditioning involves a shift towards natural refrigerants like carbon dioxide (CO_2), ammonia (NH_3), and hydrocarbons (such as propane and isobutene). These refrigerants have low or zero ozone depletion potential and significantly lower global warming potential compared to HFCs.
3. Advanced System Designs: Future systems will likely incorporate advanced design features to optimize efficiency and performance. This may include variable-speed compressors, smart control systems, and improved heat transfer technologies. These innovations will maximize energy savings and provide more precise temperature and humidity control in various environments.
4. Integration with Smart Technology: The Internet of Things (IoT) and smart technology will play a significant role in the future of refrigeration system. Smart thermostats and sensors will enable remote monitoring and control of cooling systems, optimizing energy usage, and providing personalized comfort settings. Integration with smart grids will also allow for demand response capabilities and load balancing.
5. Thermal Energy Storage: Thermal energy storage (TES) systems will become more prevalent in the future. These systems store excess cooling capacity during low-demand periods and release it during peak demand, reducing the load on the power grid. TES can help shift energy consumption to off-peak hours, improving energy efficiency and reducing electricity costs.
6. Waste Heat Recovery: Waste heat generated by cooling systems can be harnessed and utilized for other purposes, such as water heating or space heating. Future refrigeration and air conditioning systems may incorporate heat recovery technologies to capture and redirect this waste heat, improving overall energy efficiency and reducing environmental impact.
7. Green Building Standards: With the increasing focus on sustainability, green building standards and regulations are likely to evolve. Energy-efficient cooling systems will be an essential

component of green building certifications, encouraging the adoption of environmentally friendly refrigeration and air conditioning technologies.

Overall, the future of refrigeration and air conditioning will be driven by a combination of energy efficiency, sustainable refrigerants, advanced system designs, smart technology integration, thermal energy storage, waste heat recovery, and adherence to green building standards. These advancements aim to reduce environmental impact, minimize energy consumption, and provide comfortable and sustainable cooling solutions.

6.3 LIMITATIONS

1.The design and implementation of a hybrid system is little complex and relatively challenging and it require a higher investment.

2.The ROI is taking a huge time so lot of customers are not preferring this system.

3.This types of hybrid models are more beneficial for hotels, hospital, industries

4.The initial cost of purchasing and installing the refrigeration systems can be significant, especially for larger or more complex systems. This can pose a financial barrier for some individuals or businesses, particularly in developing regions or small-scale applications.

5.Refrigeration systems have a specific cooling capacity based on their design and specifications. If the cooling demand exceeds the capacity of the system, it may result in inadequate cooling performance or the need for additional cooling equipment.

6.The performance of refrigeration systems can be affected by ambient temperature and humidity. In extreme conditions, such as very high temperatures or high humidity levels, the cooling capacity may decrease, and the system may struggle to maintain desired temperatures.

7.Refrigeration systems often require dedicated space for installation, particularly for larger commercial or industrial applications. The size and layout of the cooling equipment, including condensers, compressors, and evaporators, need to be considered during the design and installation process.

7.4 References

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