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CST based solar refrigeration using vapour absorption systems

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Abstract
Space refrigeration is a process that requires a lot of energy. The demands for refrigeration are highest during the day, especially during the summer season. India experiences high temperatures for the majority of the year, making solar refrigeration a very sought after technology. However, in rural areas, where there is a lack of electricity and resources, other sources of heat or electrical energy must be used.
Combination of a CST and vapour absorption system could potentially solve both of these problems at once while being sustainable. This report discusses the pros and cons of both individual systems and their feasibility in the future.

Introduction

Concentrating Solar Thermal Power

Concentrating solar-thermal power (also known as CSP) technologies can be used for electricity generation, converting energy from sunlight and accumulating it in the form of heat to be utilised later.
Like solar power systems, where solar panels are used to convert sunlight into electricity, the sun's energy is harvested and turned into electric power. Despite their many similarities, there are fundamental differences between PV and CST systems.
PV converts radiation directly, while CST uses a system of mirrors to focus sunlight onto a single point. This energy is stored as heat and used to drive turbines to generate electricity. CST is unique because of its ability to store energy, making it a very versatile and reliable source of renewable energy.
Integration with different power sources is also possible, creating a hybrid power plant. CST and thermal power plants using natural resources (fuel, biomass etc.) are one example of such [1].

CST (Types and process)

The CST technology can be roughly divided into 4 major types.

1. Parabolic Trough Systems

a. Solar energy is concentrated by curved, trough-shaped reflectors, which then directs the rays onto a receiver pipe. The thermal oil within this device contains energy which is then used to generate electricity using steam [2].

2. Power Tower Systems

a. This system uses mirrors (called Heliostats) to direct sunlight onto a receiver, which allows it to be used effectively.

3. Linear Fresnel Systems

a. A large number of collectors are used, each placed in a row. The mirrors are positioned so that the sun's rays are directed onto the receiver pipe above.

4. Parabolic dish systems

a. A parabolic-shaped dish is used to concentrate energy onto a receiver. The receiver has a tracking system that allows it to follow the sun throughout the day. This dish is capable of reaching extremely high temperatures.

Fig 1: Parabolic CST system

Advantages of CST

One of the main benefits of using CST is that it is renewable. Its supply is never-ending, can be used continuously and leaves a low environmental impact, compared to other sources of power.

Unlike other sources, CST uses the Earth's natural resources in a way that is more environmentally friendly and reduces the extent of climate change. CST systems also provide a reliable source of electricity, which is a major issue in a country like India. Other renewable sources like solar photovoltaics, wind power are susceptible to external factors like weather and may not always provide consistent power. CST is unique in that it is able to store energy for later use, which makes it more predictable and reliable.

From a technological standpoint, CST is fundamentally different from what we've used in the past, but it's possible to integrate it with existing power plants. Steam-based power plants that already exist can easily be integrated with CST. The daily operating cost for a CST plant is much lower than nuclear and pure hydrocarbon-based plants due to its simple operation and maintenance.

With all these factors in mind, CST can be used in combination with other sources of energy, creating a more reliable and secure energy grind. This technology could help meet future electricity needs, as demand seems to be rising on a daily basis.

Disadvantages of CST

Although the technical and future potential for a CST based electricity grid seems bright, it does bring about certain unique downsides.

Renewable sources of energy are popular because they are environmentally friendly. However location is a very important factor for efficiency. Like wind power farms and solar PV, CST plants require a large area to operate, making them inefficient in densely populated areas.

CST also needs a lot of water to work, to drive steam turbines and cool thermochemical reactors. Seawater could be seen as a potential solution to the issue.

Even if the daily operating costs for CST systems are lower than its counterparts, storing energy for future use is still expensive. Molten salt is commonly used as a storage and generation medium, but its operating range is somewhat limited and needs to be kept at a specific temperature to remain operational.

Vapour Absorption System (VAR)

Vapour absorption refrigeration systems include all of the processes in a vapour compression refrigeration system. It uses refrigerants such as ammonia, water, or lithium bromide to keep the air cool. The refrigerant condenses in the condenser and evaporates, producing a cooling effect and releasing heat in the atmosphere.

The major difference between this system and other typical systems is the way the refrigerant is compressed and suctioned in the refrigeration cycle. In a vapour compression system, the compressor removes refrigerant from the evaporator and subjects it to high pressure.

In the vapour absorption cycle, two different devices called absorbers and generators work together to create a vacuum and then a compression.

Another major difference between vapour compression and vapour absorption cycles is the way that energy is input to the system. The energy input to a vapour compression system is determined by the mechanical function of an electric motor driven by an electric motor. Energy input into a vapour absorption system is typically given as heat [3].

Inner components

1. Condenser
2. Expansion Valve
3. Evaporator
4. Absorber
5. Pump
6. Analyzer
7. Generator
8. Pressure reducing Valve

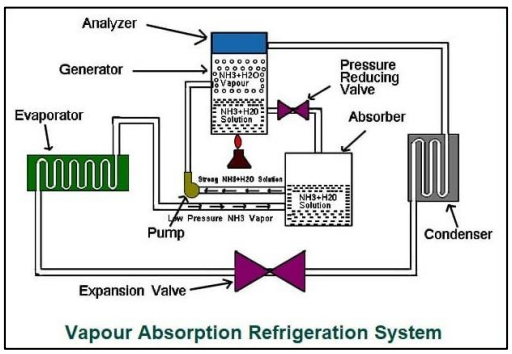

Fig 2

Inner workings

- When vapour NH3 from an evaporator enters into the absorber, it gets absorbed by the water and NH3 molecules to form a strong NH3 solution. It is then delivered to the generator via a pump.
- Inside the generator, the NH3 solution is heated with the help of heating coils. High pressure vapour is formed.
- Upon entry of the high pressure vapour into the condenser, heat is extracted from the vapour, liquifying NH3.
- It then enters the expansion valve and we obtain low pressure vapour at the other end.
- The main effect of cooling for refrigeration is obtained in the evaporator.
- Heat present on the surface of the coil of the evaporator is absorbed by the cold ammonia liquid.
- This causes the cold ammonia liquid to convert to its vapour form. The heat loss of the evaporator causes a cooling effect to take place that acts as our source for refrigeration [4].

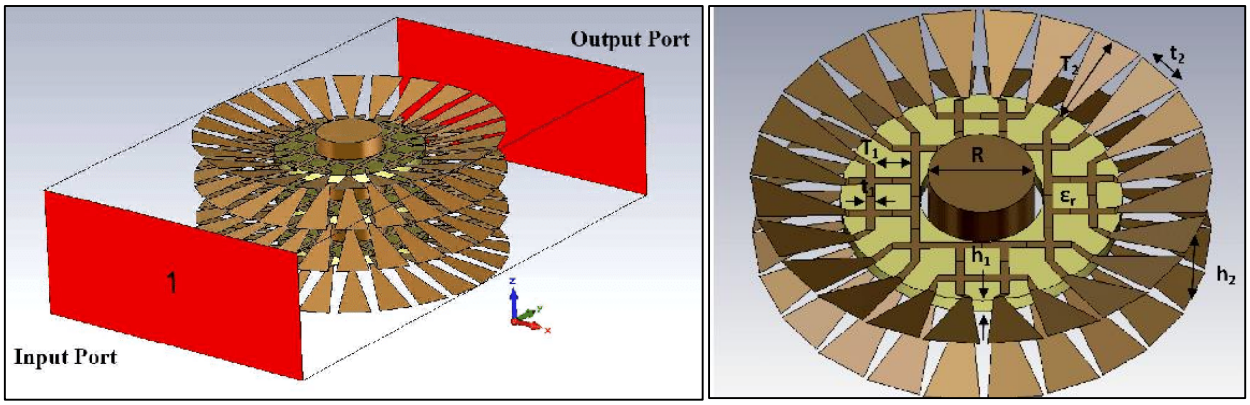

Fig 3: CST Cross Sectional Diagram

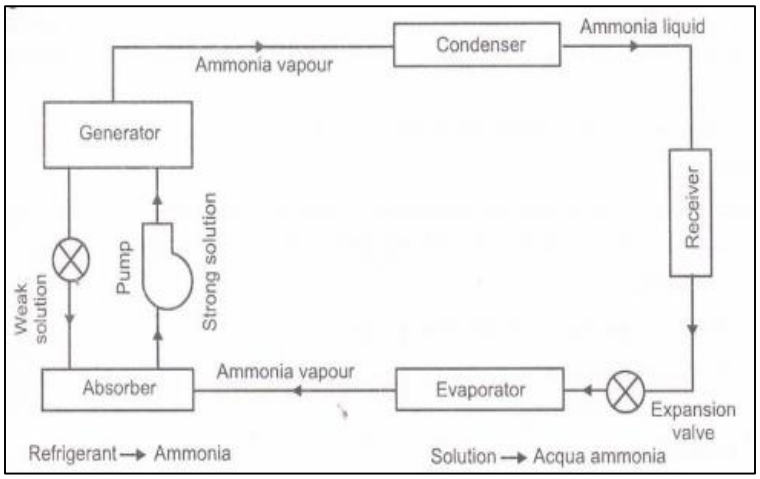

Fig 4: Vapour Absorption System Diagram

Different VAR Systems

1. Simple salt and water system

a. A common type of refrigeration system used in large commercial plants uses a solution of lithium bromide or lithium chloride salt and water. Water is evaporated from the coils that will be chilled under low pressure. A lithium bromide/water solution absorbs water. The system then uses heat to drive the water out of the lithium bromide solution.

2. Water spray absorption refrigeration

a. You can use air, water, and a salt water solution to achieve a cooling effect for this system. The intake of warm, moist air is passed through a spray of salt water. The spray lowers the humidity, but does not significantly change the temperature. The air is cooled by a spray of fresh water, which makes it more humid and warm.

3. Single pressure absorption refrigeration

a. The refrigerator uses three different elements for cooling: ammonia, hydrogen gas, and water. The recycling process is endless, and all hydrogen, water and ammonia are reused endlessly. The system is pressurised in order for the boiling point of ammonia to be higher than the temperature of condenser coils. The gas mixture flows through a pipe from the evaporator into the absorber. The mixture of gases contacts water, causing the gas to absorb water vapour. The gaseous ammonia dissolves in the water, while the hydrogen gets collected at the top. The solution flows to the generator where heat is applied to boil off the ammonia. The pure ammonia gas then enters the condenser for the cooling effect to take place.

Advantages of VAR

- Low number of moving parts
- Absence of compressor
- Low grade energy like heat can be used.
- Carries potential to be applied in rural areas where there is a lack of resources.
- Easy to control, with accessible tools.
- Load variation does not alter efficiency of system too much
- Environment friendly and a lower overall cost.

Disadvantages of VAR

- Operating time is much higher AKA the cooling takes longer to take effect.
- Bulky in size, difficult to transport.

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