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Research on solar energy for domestic use in Vietnam

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ABSTRACT: The article proposes a hot water and cooling supply system using solar energy in family houses. The author calculates, designs, prepares and tests the system under climatic conditions in Vietnam. Thereby, improve each part in the system to increase energy conversion efficiency. Experiment shows that this system can be applied in areas without electricity supply system and contribute to energy saving for households and improve quality of life.

KEYWORDS: solar energy, hot water, cooling supply, hot water and cooling supply system, adsorption refrigeration technique.

I. INTRODUCTION

Vietnam stretches along the eastern coast of Southeast Asia. The land area is 329,566 km² with a length of about 1000 km. The territory stretches from 8°10' n. l. to 23°24' n. l. and from 102°10' e. l. to 109°30' e. l. Vietnam locates in a tropical to south-tropical climate. The average solar irradiation per year is approx. 850 W/m².

In the present, the supply of electrical energy cannot meet the energy requirements in Vietnam. Particularly in rural areas, the infrastructure for the supply of electrical energy is still underdeveloped. Some parts of the country are not supplied at all, in other parts the supply is sufficient for lighting. Following are some causes:

Currently, the power generation capacity is approximately 43.8 GW (as of 2017). On the other hand, Vietnam is one of the most densely populated countries in the world with a population of about 95 million people (as of 2017) or with more than 290 inhabitants per square kilometer.

As a result, the annual per capita consumption of electricity is relatively low. The state electricity network is not well developed. It mainly focuses on the cities.

In order to reduce this problem of electrical energy supply and especially to increase the standard of living in rural areas, efforts are being made to develop applications of solar energy. It would be desirable if a complete solar technology system were to be available for domestic supply.

II. CONCEPT OF SOLAR HOT WATER AND COOLING SUPPLY FOR A REFERENCE HOUSE

The conception and interpretation of the solar technique is based on a so-called reference house, which is typical for the rural areas of Central and South Vietnam in terms of its construction and size. The total energy requirement is based on the way of life and the number of householders. It is necessary to provide hot water during the day as well as cooling, which can also be produced for food preservation at night. This is referred to as a solar hot water and refrigeration system. A solar Stirling engine is considered as a pump drive for overcoming differences in height during water transport. Suitable solar collectors are to be used for water heating. For refrigeration, an adsorption refrigeration unit appears to be advantageous in the overall system.

So far, a large number of solar collectors have already been described and investigated. Thus, it is assumed that basic solutions are known. There are also sufficient products with partly excellent properties on the market of industrialized countries. As the end-users are among the poor population, imports are to be avoided for economic reasons. The challenge is to find a technical solution and a material selection, which enables a local production under the given technological conditions.

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Simple and cost-effective sorption systems for refrigeration, which have already proven themselves in practice, have so far been found to have few references in the technical literature. The solution to this task does not seem easy, because despite all efforts, no technical solution has yet been successfully implemented.

Sorption aggregates for refrigeration are thermodynamically coupled right-left processes. They contain a thermally driven right process, which supplies the drive energy for the link process. Sorption units operate internally with a pair of materials, the refrigerant (sorpitive) and the sorbent (sorbent).

In Germany, the practical use of a solar sorption system for the air conditioning of a hospital has been successfully tested [28]. A little more difficult compared to air-conditioning, which, in principle, works with temperatures between 5 and 20°C, is the refrigeration to keep food, freeze or produce ice, which requires refrigeration below 0°C. This is a demanding scientific and technical task [1, 2, 3].

The solar energy serves as a heat source in the desorption process (legal process) to drive the solar adsorption aggregate. On the other hand, a heat mover is required in order to dissipate the waste heat of both the right-hand drive process and the left-hand cooling process (adsorption process). This can be ensured during the day by heat exchange with the air and at night by cooling water.

Compared to an electrical refrigeration system, the adsorption refrigeration unit has a number of advantages:

- no use of CFCs and CFCs, i.e. environmentally friendly
- no rotating parts
- low vibration and low noise operation
- longer service life, low maintenance.

In addition to the advantages, the adsorption unit also has a number of disadvantages:

- bulky equipment, thus more space requirement for installation
- lower power
- slow start-up phase after start

A special component for water pumping is the solar Stirling engine. It is already operating at a temperature level below 100°C. Absorbed solar radiation energy serves as heat source for the force process. The ambient air or cooling water can be considered as heat sinks. Coupled with a suitable water pump, it can be used for decentralized supply of drinking and industrial water.

The calculation, design, production and testing of the solar collectors and the adsorption refrigeration system as well as the development of a Stirling engine at the University of Danang (Vietnam) are described in full in the present dissertation, starting with the description of the reference house and typical requirements for the supply. In addition to solving many individual problems, it is also necessary to develop a Visual Basic program to calculate the collectors. The experimental results and the experience gained are evaluated [4, 5].

III. DESCRIPTION OF THE REFERENCE HOUSE

A typical house in rural area is single-storey and has a floor area of approx. 70 - 100 m². Concrete columns bear the concrete flat roof, and the walls consist of brickwork. In Vietnam such a building is called "nhà mái bằng". Additional floors can be built if more space is needed. The house is divided into several rooms (see fig. 1). The main entrance is at the front, behind it are the guest room, and the bedrooms. The bathroom and the kitchen are at the other end of the house. A corridor running along the long side leads to the rooms.

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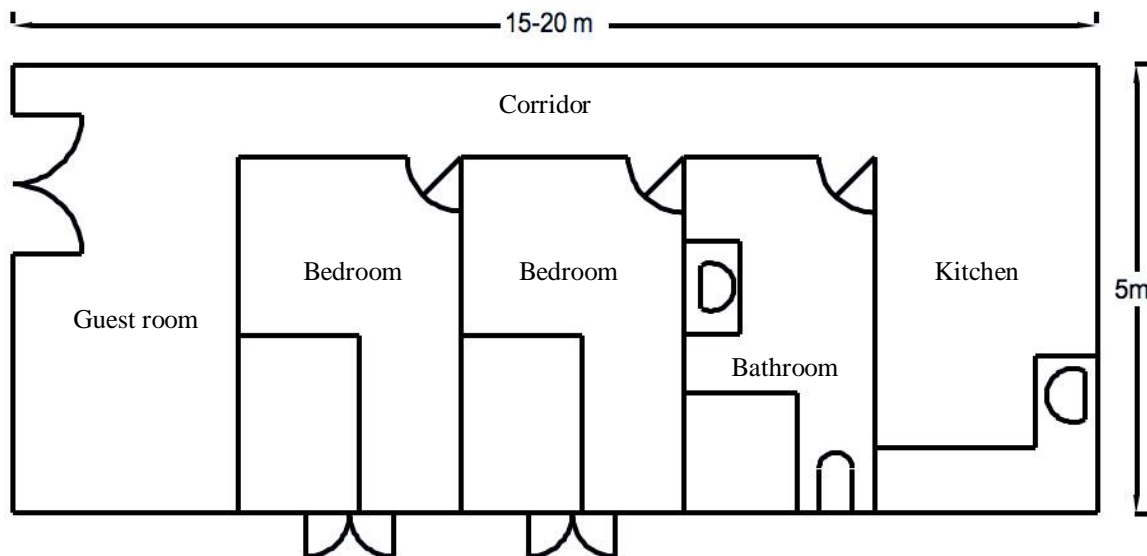


Fig.1 Floor plan of the reference house

The height of a storey is about 3.2 to 4.0 m. The roof provides enough space and stability to place a water tank. The supply of clean water is still a major problem in Vietnam, as the state's central water supply is not yet well developed. In rural areas and in most small towns, there is no state water supply. That is why people build private well and then pumps the water into storage containers [1, 3].

A core family in Vietnam has 4 people, i.e. parents and two children. Previously, a couple had several children, but today each family should have only two children. People need cooled drinking water and hot water for showers as well as dishwashers. Vietnam is located in the tropical or subtropical climate zone, and the temperature is therefore high. Vietnam has annual average temperatures between 24°C and 29°C. In the summer, you do not need hot water for showers, but it would be desirable to raise the level of prosperity if the housewife had hot water for rinsing or cooking. In the tropical climate the food spoils quickly. It would be quite good if the inhabitants had a refrigerator there. However, in rural areas, this is still an unsolved problem.

The solar supply system for the reference house is intended to meet three requirements: providing drinking, clean water and hot water as well as cooling for four people.

IV. ESTIMATION OF ENERGY REQUIREMENTS

The consumption of drinking and clean water for four persons per day is approximately 1.2 m³. This water is pumped from a well (suction depth approx. 3-5 m) into the storage tank on the house roof. The distribution to the dispensing points in the house takes place by gravity.

The requirement of hot water for four people per day is about 200 l. The temperature of the hot water should reach 85 - 95°C.

The power of the cooling box must be designed to be about 100 W. The temperature in the cool box should reach from -7 to -10°C. This is sufficient to cool the routinely occurring amount of perishable food and to produce ice for the cooling of beverages. The total cooling capacity corresponds to an ice production of 5 kg per day.

The principle of a solar hot water and cooling system is shown in Fig. 2. It consists essentially of the following main components: a tube collector, an adsorption refrigeration unit and a solar Stirling engine as the drive for the water pump. The tube collector (1) is placed directly on the flat roof. The cold water supply for the collector is via the hot water tank (2). The collector works in the natural environment. In the hot water tank is a sorption, which was filled with activated carbon and methanol as a pair of adsorption. Sorption is a heat exchanger whereby the heat from hot water is delivered to the activated carbon and vice versa the heat is transferred from the activated carbon to the cooling water.

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The cold box is placed in the kitchen and connected to the sorption and the condenser. These components, together with the collector, form the solar adsorption refrigeration unit.

The solar Stirling engine is placed on the flat roof. If we have space, we can leave the Stirling engine on the ground next to the house. The Stirling engine converts solar energy into mechanical work. It is used to drive the water pump. This promotes the (cold) well water into the water Storage tank (11) on the flat roof.

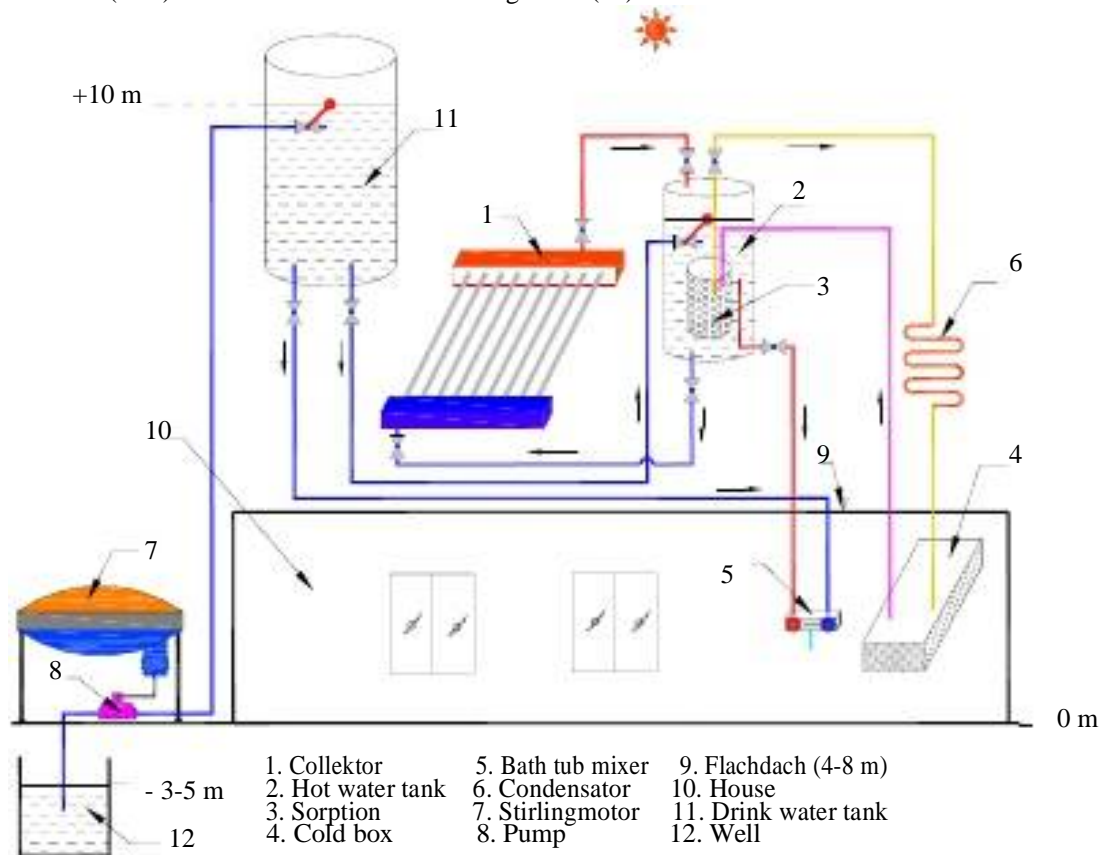


Fig. 2 Principle of a solar hot water and cooling supply system in the reference house

All materials required for manufacturing the system are available in Vietnam. This reduces the price, which is an important element as the population in rural areas is mainly poor. Furthermore, the construction of the system should be simple. No particular equipment is required to make the components.

The experimental investigations took place in Vietnam, under laboratory conditions and as a field test under the given Vietnamese climatic conditions.

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The experimental investigations took place in Vietnam, under laboratory conditions and as a field test under the given Vietnamese climatic conditions [6, 7].

V. DESIGN DATA

According to the experimental investigations of the individual parts such as the collector, the adsorption refrigeration unit and the Stirling engine, the design for the solar drinking, domestic, hot water and refrigeration supply for a reference house is considerable [10, 11].

In order to meet the demand for hot water and cooling for four persons, 8m² of collector area were provided on the flat roof. Each collector has a surface area of 1m² and is connected in two groups in series. In each group, 4 modules are arranged in parallel. With this assembly, the hot water temperature is higher than in only parallel arrangement. It has many advantages in winter, with the absorbed solar energy being smaller. The temperature is sufficient to take the adsorption refrigeration system into operation. Even in winter the warm temperature can be reached above 55°C.

In order to absorb the solar radiation as much as possible, the collectors are inclined. In Vietnam the optimum angle is 16 to 19 degrees.

The collectors heat more than 200 liters of hot water per day up to 95°C in summer under a tropical climate. At the same time, they provide sufficient heat for desorption process in the adsorption refrigeration system during the day. At night, they absorb the heat transfer from the adsorption process to the outside air. To ensure the operation of the absorption refrigeration system and also to increase the efficiency of the system, tubular collectors are provided in an inclined direction with natural circulation for the reference house. The cooling box has an evaporation area of 0.22 m² and offers a cooling capacity of approximately 100 W or 4 to 5 kg of ice per cycle [12]. The condenser has a heat transfer area of 0.62 m² and can be placed on the roof or in the house. The sorber has a heat exchanger area of 6.74 m², in which about 65 kg of activated carbon has been filled. The methanol quantity of 5 l is in the cold box. In order to meet the demand for drinking and service water, the Stirling engine was used as a drive for a water pump. It has an absorber area of 1.9 m² and a diameter of 1.6 m. It can boost the water volume from 1 to 1.5 m³ per day up to 10 m high.

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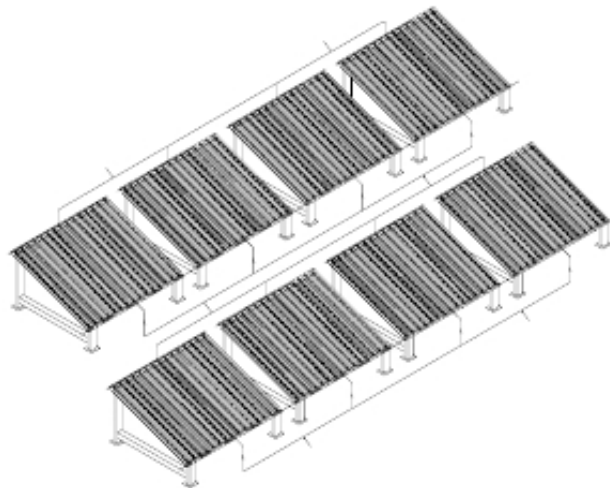


Fig. 3 Assembly of collectors

VI. CONCLUSION

The aim of this research was to develop three solar systems for a reference house not only in Vietnamese climatic conditions but also in other tropical regions. These are:

- a collector for hot water supply
- a complete hot water and cooling system
- a Stirling engine for drinking and service water supply.

The three parts have been combined into a solar home supply system and form the main focus of the research. According to the technical and economic conditions in Vietnam, these parts should be designed, built and maintained with little maintenance. As a result of these requirements, the cheap production materials available in Vietnam were selected.

Within the framework of the experimental investigations carried out, the solar collector, the adsorption refrigeration system and the Stirling engine were calculated, constructed and manufactured in various variants and tested under laboratory conditions as well as under natural climatic conditions.

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