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Run In and Usage of a Solar Assisted Heat Pump System

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Abstract: - Renewable energy resources have become important because of the increasing costs of fossil fuels. Up to now there has been little deregulation of the fossil fuel market and, therefore, the customer is not in the same position as with the electricity market where there is competition and an incentive to shop around for the best supplier. A good strategy for the customer is therefore to become less dependent on fossil fuels by installing renewable energy systems such as solar-assisted heat pumps. Significant research has been carried out in the field of solar-assisted heat pump system since the 70s but most of the technologies developed have stayed at the research level due to two primary reasons, namely poor control strategies and the inability to keep operating temperatures high enough to realize high coefficients of performance over the full year. Within the frame of the EC funded Endohousing project these issues are being investigated. The research focuses on the development of a system comprising a new unglazed solar roof collector and hi-tech control strategies to manage the effective movement of thermal energy in different sections of the system. The project has set up three houses using the endothermic technology. This paper is concerned with the initial set up, commissioning and run in of the systems. An evaluation of the first results of the technology is presented so that overall system optimisation can follow.

Key-Words: - solar assisted heat pump, endothermic technology, simulation, control, renewable energy, heating system, solar roof

1 Introduction

The emission of CFCs and halogenated CFCs arising from heating, air conditioning and cooling systems has one of the greatest effects on the world's climate by contributing to the greenhouse effect which is responsible for destroying the earth's ozone layer. These worries are widespread and many international efforts have been established to assess scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation [1]-[2]. In this respect the consumption of fossil fuels to provide energy for the various sectors in every society is causing much concern due to the direct or indirect contribution to the greenhouse effect as a result of their CO_2 emissions. Furthermore, cooling / air conditioning and heating systems which rely on fossil fuels, are major offenders when considered on the global scale. In the case of heating systems the situation can be improved by avoiding heat losses by reducing transmission through walls and windows by better insulation and reducing levels of ventilation. This has been the subject of much research work over many years. There remains, however, much scope for optimising heating/cooling technologies based on renewable energy systems. There are many such technologies being investigated, namely solar, wind, hydro, biomass, photovoltaics, etc One of these that could have good potential for the future uses solar thermal energy coupled with heat pumps, the technology is normally referred to as solar-assisted heat pumps for domestic housing and forms the focus of the current paper.

Solar-assisted heat pumps utilise solar thermal energy to improve the effectiveness of a heat pump to deliver thermal energy in various applications [3]-[9]. The current paper presents a novel approach referred to as endothermic technology where large solar collectors are integrated into a building to form part of the building fabric (eg. the roof) and these are coupled to energy stores to collect vast amounts

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of, normally low-grade thermal energy. The energy collected is upgraded via a heat pump for heating or vice versa for cooling or for hot water. The concepts of the technology have been tested in the UK and early work has shown that it can reduce energy consumption for space heating by up to 50% [10], [11]. The technology is now being further developed and demonstrated at EU level under the EC funded Endohousing project so that its full potential for providing the thermal energy for domestic space heating and cooling and hot water can be established. Endohousing aims to assess this potential by designing the various system components and using these in setting up a number of test “endohouses” in different climatic regions in the EU. The endosites are to be monitored during the cooling and heating seasons to make the final assessment.

THE ENDOSYSTEM -STATE OF THE ART

In the case of heating systems the situation can be improved by avoiding heat losses by reducing transmission through walls and windows. This has been the subject of much research work over many years. Many modelling and simulation programmes have been produced for this purpose (TRNSYS [12], Matlab [13], ApacheSim [14]). Hube [16] did a lot of research in the field of solar optimized buildings by focusing on the solar energy which the building is using. By insulating houses, or using transparent insulation a solar optimized building can be realised but it needs a big investment especially in the case of retro-fitting houses. As a result the insulation work on existing houses is realized over a longer time period, year by year where the house owners make the investments to improve their insulation in an incremental way. This represents a very time consuming and expensive way of saving energy.

Using renewable energy resources is at present not very cost efficient. In comparison to the savings in running energy costs the capital investment needed is extremely high. The fossil fuels are still not “expensive” enough for the renewable energies to be widely perceived as being competitive alternatives. In Germany the ratio of renewable energy sources is high in comparison to other countries because of the co-funding programmes introduced by the government. But funding of renewable or innovative techniques is a good solution for establishing a market for the techniques but finally it should be possible to sell the product for a competitive price on the market. Funding is therefore not a solution for the long term.

2 Demonstration Houses

The solar-assisted heating system with the novel solar roof collector is tested during the current Endohousing project. Therefore it is planned to build five houses equipped with the solar-assisted heat pump system. To get a general overview about the system behaviour over Europe the houses are built in latitudes ranging from ≈61º in Sweden to 35º in Cyprus. During the testing phase the best practice for the operation will be sorted out as well as the best system components like stores and especially the piping work.

One of the houses is in Germany (Fig.1). The German endohouse is located in Soest, a small City with 50,000 inhabitants in the middle of Germany. It was decided to build a small model house in the first stage. The endohouse is an office building constructed in 1999; it has a one storey building with an attic floor and a basement. For the Endohousing project, only the office and a workers room is used for the heating.

For the endoroof, 15 m² were installed on the top of the roof. The gable of the building is facing south so that the collector roof is facing west.

The weather conditions in Soest are typical for the middle of Germany. Daylight hours are up to 15 hours during the summer (average temperature around 20°C, peak temperature around 35°C). During the winter temperature could be below zero (average around 2°C, minimum around –15°C) with considerable snowfall.

Fig. 1: The German Endohous

2.1 Installed System Technique

The Soest endothermic system consists of the following components:

- The collector roof with an area of 15m² is build on the top of old tiles. The collector is an extruded alumina profile through which a heat transfer fluid (with glycol) is circulating. A dark coating was chosen because of the higher thermal performance of the planks. The planks are connected at the ends with a flexible tube. To increase the turnaround time of the fluid always two planks were connected in series.
- The heat pump is provided by IVT Industrier, a partner from Sweden. It is a heat pump which could provide an output of 6 kW thermal energy for space heating and hot water. It also comprises a backup electricity heater when solar energy is insufficient to drive the endothermic system.
- The cold store which is connected to the roof and then to the heat pump and is functioning as a heat buffer for the roof. The size for the tank is 160 litres. The cold store is filled with glycol as well in case that temperature drops below zero during winter time.
- The hot store which is connected to the heat pump and then to the heating distribution system. The hot store and heating system is filled with pure water.

All piping work is done with copper pipes and the connections were done by compression fittings. The main components are shown in Figs. 1 and 2.

Fig 2: The endosystem's internal components

In case of severe winter periods a gas heater is installed as a backup solution which is absolutely necessary within the prototype testing phase but it is expected that the final endothermic technology will form a primary thermal energy system and the backup will not be needed but needs to be included until confidence in the technology has been gained. The space heating is realised by warm air convectors with a low supply temperature and one office room is equipped with a floor heating.

2.2 Monitoring equipment

To be able to access the endothermic system a data monitoring system is included in the design. This comprises a programmable IQ3Xcite Controller from TREND. This controller is equipped with a web based module which enables an authorised user to check and adjust and save the monitored data. The controller is connected to the internet via broadband including a fixed IP address, which is necessary for the communication between the system and the supervisor.

The following parameters are being monitored:

Weather station parameters:

- Wind speed
- Temperature
- Humidity
- Brightness
- Rain (Yes/No)
- Global radiation in the angle of the roof

Monitoring Sensors

- Flow Sensors from KOBOLD Messring.
- TREND monitoring equipment:
  - 1 IQ3XCITE/96/GER/100-240: Controller for overall system
  - 2 XCITE/IO/8UI/GER: Extension module for Controller to allow extra inputs and outputs
  - 10 T/TFR-4/10: Temperature sensors (Thermistor direct contact to the pipe)
  - 2 EM/1/N/230: Electricity meters for energy consumption monitoring
  - 1 EM/3/N230: Electricity meters for energy consumption monitoring
  - 1 963S/CD/3USER/GER: Supervisor software for monitoring work

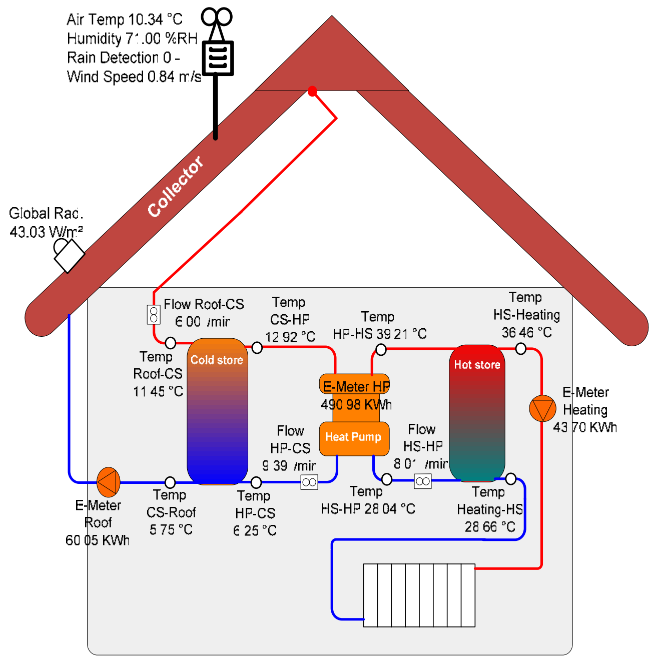

Fig 3: The online monitoring view

3 Efficiency of the system

It is planned to evaluate the system performance by using four metrics. These are 1) Set-point error tracking; 2) Heat pump coefficient of performance (COP), 3) Overall system efficiency, and 4) Comparison of efficiencies with conventional systems. This assessment will be carried out over different periods (1hr, 24hr, 1 week, 1 month, etc). The results will lead to different optimisations of the system.

In the following these evaluations are carried out for the initial data that has been collected to date. For evaluation the reference data of the heat pump will be taken:

- Input/Output power in kW at a Temperature level 0/35°C is 5.9/1.3 which is leading to a COP of 4.5.

- If the temperature difference is 0/50°C the In- and Output power are 5.4/1.7 which equals to a COP of 3.2.

Out of the first results from the data collected is the evaluation of the COP. The result shows that if the outside temperature drops below zero than the efficiency of the system decreases dramatically. In Table 1 some COPs from March 2006 are shown.

Tab. 1: COPs of the heat pump

Date	Cold Store Temperature	Hot Store Temperature	Heat capacity	COP
13.03.2006 17:19	15°C	43°C	6.2kW	5.18
18.03.2006 18:16	17°C	42°C	6.17kW	5.4
19.03.2006 17:05	16°C	37°C	7.2kW	6.10
20.03.2006 18:47	16°C	38°C	6.12kW	4.4
21.03.2006 12:20	4°C	47°C	4.8kW	3.2
21.03.2006 15:21	19°C	36°C	6.99kW	6.7
21.03.2006 18:28	16°C	39°C	6.14kW	4,12
27.03.2006 20:27	17°C	38°C	4.52kW	4.15

The evaluation of the COPs shows that it is possible to reach very efficient running of the heating system during day time. But a major problem will occur during cold winter times. During February 2006 when the outside temperature was below -5°C during the night the temperature in the cold store dropped down to -8°C at that temperature the heat pump was switching off for safety reasons and was restarting after 3,000sec. This switching of the heat pump could lead to damage of the heat pump. Therefore this situation has to be improved by applying more effective control strategies like loading the hot store (heating buffer tank) during day time when the outside temperature is higher and by the installation of bigger stores which can store a bigger heat capacity. But even with the current system as it is described above, a higher COP over the year could be reached because of the time in-between the seasons; like winter-spring and autumn-winter, where the system is running more efficient than an ordinary ground source heat pump.

In the case of the presented system there is the possibility to connect a ground source parallel to the cold store which will be used when the outside temperature during night time is below zero. This is planned within the next month.

The main component of the system is amongst the heat pump the collector roof plank; fig 4 is shows the design of the flat collector. The collector should be able to collect the ambient energy and if available the heat produced by solar radiation. The heat pump efficiency will not increase if there are temperatures higher than 20°C in the cold store. The only interesting possibility to get higher temperatures could be a bypass from the roof direct to the hot store without using the heat pump.

The second reason why such a collector was chosen was that the system can although be used as a cooling system by transferring the heat from the rooms thought the roof the atmosphere. This would not be possible with the normal thermal solar panels.

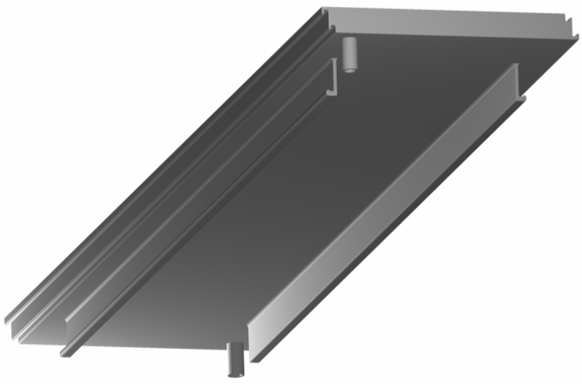

Fig 4: Flat collector design

To present the performance of the collector the outside temperature and the collector outlet temperature is compared to the global radiation shown in fig.5.

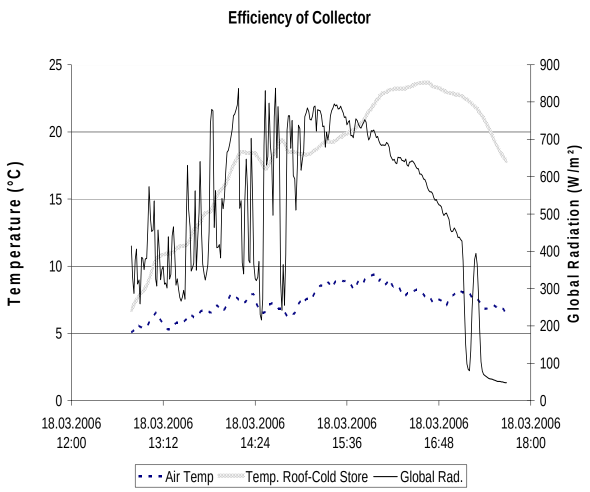

Fig 5: Collector Efficiency

4 Future work

Optimisation of the system's performance will be done by applying advanced control strategies, based on the experiences which were made during the testing period. It is planned to extend the German system by connecting a ground collector/storage which will help to overcome the lack of heat during strong winter periods.

5 Conclusions

The paper has presented initial results from a novel solar-assisted heat pump based technology that is being developed within an EU funded project. Now the technique is being tested by monitoring the data from different sites. The results after the data analysis will be used to optimise the system technique and try to develop a comfortable heating and cooling system for the domestic housing.

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