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Solar Combi System Combined Space Heating and Cooling System

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Abstract— To Study the outcome of a Solar Space Heating and Cooling Combinational System, by integrating both (Space Heating and Air Conditioning) system into a single system. This paper deals with two different solar systems, almost opposite to each other, which are combined together so as to result in more economic and energy efficient system. The system is backed up with a conventional heating and cooling system so as to make it more reliable than a complete solar system. Further this combi system can be improved depending upon the climate of the particular place or region, by adding other solar components and as well by changes in design so that it can be made more simple, energy efficient and economical. This type of solar combi system will be more effective because it will give the both type of result for the heating process as well as cooling process. It will give more advancement of thermal system and increase the efficiency and give suitable green energy by the use of a single system in different environment need. This contains mainly different sections to make a suitable combi system like solar section and its storage sections with a suitable control system used to control all sections in integrating of all different sections.

Keywords— Solar, Combi system, Space Heating, Space Cooling, Solar Combined System, Solar Collector, Solar Thermal Storage, Control.

1. INTRODUCTION

The use of conventional cooling and heating system dependent on traditional fuel mainly electricity is increasing at quite very high rate due to modernization and global warming effect round the globe. This rate is very much high as compared to the rate of changing of our source of energy. Thus we have a tremendous need of either fastening the development of green sources for our basic needs or by changing their usage and making them dependent on renewable energy sources. As we know the prior will take a lot of time so at this state were we are very sure that the usage of our natural resources is increasing and their extinction is not far away a sudden change is very much needed. This rests us with only one option that is the former one to change the need of conventional sources and make them more dependent on renewable energy at the site of usage. Almost 50% of the energy consumption of any country is that of heating and cooling sector. If this consummation is reduced by any means or the load is shifted into a rentable source of energy without

decreasing its reliability then it would be the best solution for all the global problems that we are facing today in the field of energy and also environmental degradation.

Solar energy would be the best form of renewable energy as it is the very mother of each and every form of energy on earth [1]. Solar energy can be used in wide manner for the solution, there are two sectors that solar energy is divided into that is Solar electricity (by use of Photovoltaic cell) and by Solar Thermal energy usage.

In the sector of cooling and heating usage of photovoltaic generated electricity sounds like a very much best solution but however when it was studied the COP (Coefficient Of Performance) of these processes is very low in photovoltaic system then in a solar thermal energy system. So seeing though it thermal solar heating and thermal solar cooling system are a best solution to our problem [2]. But in some cases both these systems are to be used that gives rise to a combined system with both attributes of heating and cooling together.

The Combi System is a very distinct System and is quite complex then different solar heating and solar cooling system. There are many more different ways

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that this system can be made more accurate and defined for specific purpose depending on the local climate and needs. These changes that may be required are discussed to some extent. However this is not the only way that it can be modified but the basic needs depending upon climate. The paper here would be a very much reference for solar technocrats for basic design that can be implemented as per their needs which may very much depend upon the requirements.

As so the system is not completely dependent on solar energy but also on auxiliary supply. We can say that, this entire system although being efficient is as much reliable as any traditional or conventional system for the purposes for which they are being used till present day.

2. SYSTEM DESCRIPTION

The construction of a combi system can broadly be classified into 4 different sections for detailed and convenient explanation. The four sections are as below:

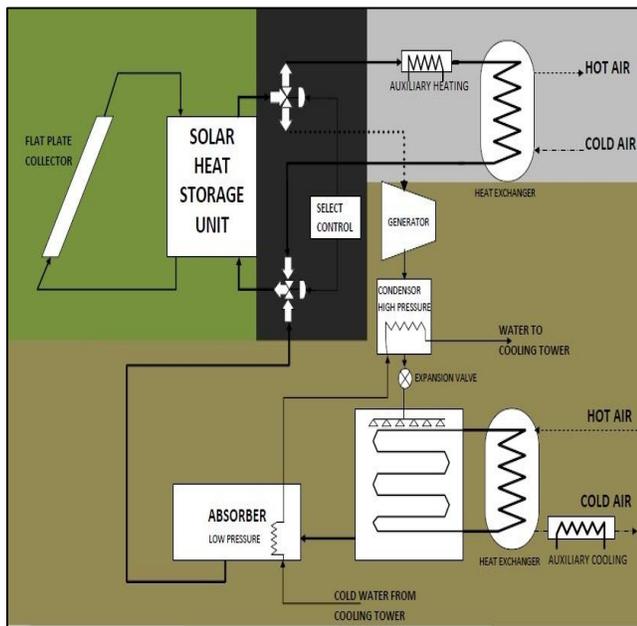


Figure 1: Block Diagram of Combi system

I. Solar Section

This section comprises of mainly two parts i.e. solar collector and solar thermal energy/heat storage unit. This unit deals with obtaining solar energy and storing it for future use i.e. in absence of solar radiation. Solar collectors are mainly of two types each with their own merits and demerits. However as per the

requirements of our system flat plate collector are more advisable than concentric one, as flat plate collector are usable even in absence of direct sun radiation i.e. it can also absorb radiant heat which is very much needed in certain situation at particular time of the year (winter mainly) when direct sun radiation are not available [3]. And also we do not require to generate very high temperature so concentric collector's over edge is dropped. Flat plate collector have efficiency less than concentric collector but here achieving high temperature is not that much needed than the absorption of radiant energy which is very much important.

Solar thermal energy storage can be acted as an optional unit depending upon the usage and requirement of the system [2]. If we require energy in the form of heating or cooling in absence of solar energy then this is a necessary part of the system. This is the part that would be responsible to provide constant energy source even in absence of sunlight. There are different types of solar thermal energy storage method each with its own merits and demerits, a user can select any of it as per the requirement taking into consideration factors like operating temperature, thermal storage capacity provide constant energy source even in absence of sunlight. There are different types of solar thermal energy storage method each with its own merits and demerits, a user can select any of it as per the requirement taking into consideration factors like operating temperature, thermal storage capacity per unit mass per unit volume, thermal conductivity, integration ability with the system, cost, availability, life, etc.[4].

Types of thermal energy storage can be were well understood by the chart below:

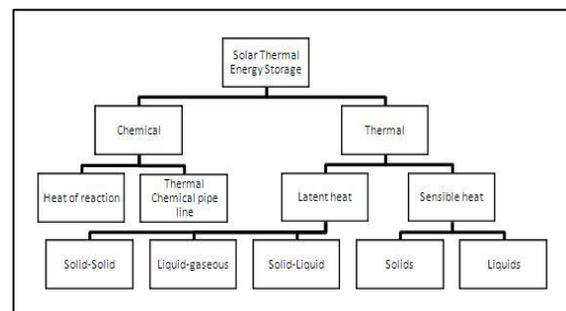


Figure 2: Classification of Solar Thermal energy Storage methods[4].

The table describes properties of certain basic methods and material used in storing thermal Energy.

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TABLE I. Comparison of different types of thermal Storage methods[4][5][6].

Property	Sensible heat storage		Latent Heat Storage Phase change material (solid-liquid)
	Water(liquid)	Rock(Solid)	
Operating temperature range	Limited (0-100°C)	Large	Large, Depending on material selected
Thermal Conductivity	Low	Low	Very Low
Thermal Storage Capacity	Low	Low	High
Availability	Everywhere	Almost everywhere	Depends on choice of material
Cost	Inexpensive	Inexpensive	Expensive
Temperature gradient during charging and discharging	Large	Large	Small
Simultaneous charging and discharging	Possible	Not Possible	Possible with appropriate Heat Exchanger
Integration with system	Direct with Water System	Direct with Air System	Indirect Integration
Life	Long	Long	Depends on material

II. Heating Section

This Section deals with providing hot air for cold environment and ventilation process it can be considered as a heater unit of our Combi system. This can be as simple as with just one heat exchanger or may result into a pretty complex system.

The complexity of the system would definitely depend upon the method of space heating, type of thermal storage material selected, amount of heat required, period for which heat is required and many other factors[2] [7].

Here described system has a simple heat exchanger with an auxiliary heater connected in series before the heat exchanger. This type of connection may not be much efficient but is quite stable and simple in maintaining the temperature that is required. The output of the stored heat is used to heat up the air from

the environment to be heated, the same material used in the storage unit is used as the hot material in the second heat exchanger and the auxiliary heater is used to heat up as per requirement of temperature [8]. This required temperature acts as a feedback to control the auxiliary heater.

For a complex system the stored heated material may not be used directly instead it may be used to heat some other material which may act as a primary heater material in the final heat exchanger [9]. The auxiliary heater can be connected in different ways for better efficiency, even a heat pump system may be used for heating it may be connected in parallel which is best way to add it. The flow of the heated material and other may also be controlled by the temperature of the hot air temperature which may act as a feed back for this closed loop system[10] [11].

Auxiliary heater may act independent also with no connection with the solar heater instead depending only upon the temperature of the space whose temperature is to be used.

Even a water heating system may be combined with this system to achieve hot water for usage. However this may heavily affect the basic idea of the system as they may use up quite amount of energy that may be used for space heating instead [8]. A geo thermal heat pump method may be used to maintain the temperature of the incoming air to the heat exchanger thus less heat is required from the storage and auxiliary source may be completely turned off and system efficiency may be improved. But this would increase the length that the air is travelling resulting into increase in size of blower and pumps used for ventilation thus resulting again into degradation in efficiency. Even a cost factor may be considered into notice as the geo thermal heat pump system is quite costly and need a large area too [1].

A heating system also employs a humidity controller as depending upon the climatic condition and also the need of the user. Sometimes water contentment may be removed from the air where as some times it may be added to achieve a constant humidity in the air supplied to the heated space.

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III. Cooling Section

The most complex and the part of most interest of the entire combi system is the cooling section. This part plays a role in providing air conditioning for the warm environment and ventilation process. This section is the most complex section due arrangement of almost 70% of the component of the entire system in completely unorthodox way.

Initially it should be clear that what is cold, it is not any physical form of energy instead it can be considered as the absence of heat energy.

For a simple explanation of the basic building blocks of this section, the section may be divided into a few parts which all together would fulfill our requirements.

Generator uses the heat energy obtained from the storage unit. It also provides secondary output of the system that is electricity which may be used or stored for future use in secondary systems like pumps, blowers, ventilation fans, control unit etc. The generator is provided with high temperature material (e.g. Lithium Bromide) so if the storage unit does not have this material as its output material an initial heat exchanger may be needed to convert the input material [12]. The temperature of the generator should be maintained so that the input material does not get crystallized, for which even sometimes an auxiliary heater may be added in the collector loop [11]. Though this may decrease the efficiency but on a long run it may keep the system stable and increase its life and however the generator would generate energy which can be compensated with that used by the auxiliary system.

Followed by the generator is a condenser that would change the heated material which is in gaseous state into liquid state at high pressure present in the condenser. Cooling is provided by the cold water supply which may be provided from a cooling tower, chiller or even though a geo thermal heat pump system would fulfill the requirement. Due to high pressure the liquid state will be achieved at a temperature higher than its boiling point [13].

The output of the condenser is passed through an expansion valve and would be sprinkled in the expander where the pressure will be low thus resulting into reconversion of the liquid into gas. However for this procedure the liquid will absorb a certain amount of heat from its environment that is the hot tubes of cooling material used in the heat exchanger from which supply of cold air to the ventilation is to be done. Thus by absorbing this heat it will cool down the fluid in the tube which in turn will absorb heat from the air supplied in the heat exchanger resulting in to cooling the air for air conditioning [12].

And finally the outcome of the expander is now condensed at low pressure in the absorber as the temperature of the liquid re-feed to the solar section should not be much high. The absorber will receive the cooling water from the same source as that of the high pressure compressor used. Now the cycle of the cooling section is completed.

This may sound quite simple but in practice a lot of factors are to be considered in a cooling system which results it into getting much more complex than any other section in the combi system. Factors like selection of material, incoming temperature of the generator, constant temperature output, and many more [14]. The table and graph provided below may help a quite in making decision for the above factors depending upon the requirement of the user.

TABLE II. Different types of Refrigerant-Absorbent for Absorption cooling machines[13].

<i>Refrigerant</i>	<i>Absorbent</i>
Water(H ₂ O)	LiBr LiI LiSCN CsF RbF or other multi salt solutions
Ammonia	Water H ₂ O Sodium Thiocyanide NaSCN Calcium Chloride CaCl ₂ Lithium nitrate LiNO ₃ Strontium Chloride SrCl ₂ Dimethyl formamide DMF
Helogenerated organic compounds	Ethers esters amides amines and others.

Although there are many different methods that can be used for cooling of space but absorption method is the most developed, reliable and generalized as compared to all other methods. In certain situation the other methods may prove to be more beneficial so for such a condition the absorption method may be dropped and other methods blocks may be replaced by the current cooling section blocks.

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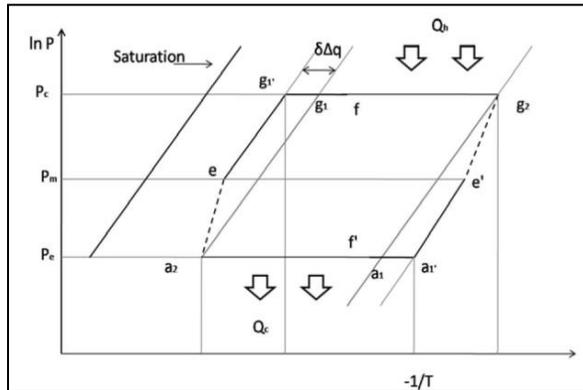


Figure 3: Classification of Solar Thermal energy Storage methods[13][14].

There are mainly 3 methods of cooling. A comparison is quite useful for the decision to be made for its selection as given below:-

TABLE III. Comparison of different types of cooling systems[14].

System	Advantages	Disadvantages
Absorption	<ul style="list-style-type: none"> Only one moving part(pump) with possibly no moving parts for a small system Low-temperature heat supply is possible 	<ul style="list-style-type: none"> Low COP It cannot achieve a very low evaporating temperature The system is quite complicated
Adsorption	<ul style="list-style-type: none"> No moving parts (except valve) Low operating temperature can be achieved Thermal COP is quite high compared to other heat operating systems 	<ul style="list-style-type: none"> High weight and poor thermal conductivity of absorbent Low operating pressure requirement makes it difficult to achieve air-tightness Very sensitive to low temperatures It is an intermittent system
Desiccant	<ul style="list-style-type: none"> Environmentally friendly, water is used as the working fluid. Can be integrated with a ventilation and heating system 	<ul style="list-style-type: none"> It cannot function properly in a humid area It is not appropriate for an area where water is scarcity Requires maintenance due to moving part in a rotor wheel

Here as it is very well known that the reliability of a solar cooling system is not that high, there is definitely a need for attaching an auxiliary cooling

system in series with the output of the heat exchanger, making the system more reliable and effective.

A cooling system similar to the heating system can also employ a humidity controller as depending upon the climatic condition and also the need of the user. Sometimes water contentment may be removed from the air where as some times it may be added to achieve a constant humidity in the air supplied to the space [15].

IV. Controlling Section

This Section is the only section that is connected to all the other sections of the combi system. It comprises of all the control units of individual as well as the overall controlling of the system. It is like a brain of the system that decides and commands how each section will work. It makes the system work in combined way to achieve the outcome that is desired by the user.

The section comprises of different parts like control valves, controllers, sensors, human machine interface, selection and decision making units and many other. It's hard to consider it as a separate unit instead it is a part of all section that deals with controlling as well as a master unit for deciding the sub units variables and working [2].

Any feature added or removed from the design may definitely affect this section. This section can have different modes of operations like heating mode cooling mode, energy storage mode and different combinations of the above modes.

The designer has to take at most care of this section as any failure in this section may lead to malfunctioning of the system as well as may damage the system. The control section should be provided power supply from a constant source as any interruption in supply to this unit may result into breakdown of the system. This section is also responsible for power saver in the system as it also controls the supply provided to the other sub section supply in all forms like power, material, and other supplies.

This section will also play a key role in development of the system. When we have complexity controlling things we find alternates and the alternates end up in being beneficial to system in terms of cost, complexity efficiency and many other ways too. It's like initially we design a control unit for a system then we modify the original system as per the control unit.

3. WORKING

Now as all the parts of the system are very well known to us we can now go through a flow of the activities that will be done by the system working in different modes of the control section. Mainly three

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primary modes will be needed to study other modes that will be combination of these modes.

i) Heating Mode (Mode-H)

This mode is mainly used in cold climate where warm air is needed to be ventilated in order to maintain the temperature inside the building. In this mode our combi system will act as a space heating system. Mainly this mode is acknowledged in winter so other important factor that would be accompanying will be lack of solar energy in the form of direct radiation. Here comes in account flat plate collector as they can also use radiant solar energy. However initially we would consider the storage unit is bypassed and only the heating section and the collector unit of the solar section is active rest all other parts are inactive except control section related to the mode as this would govern all the rest.

In practice the Mode-H is never used alone it accompanies Thermal Storage Mode (Mode-T). This is because the maximum need of warming up space is required at time in absence of sunlight like night time so for this lateral use the energy should be also stored partly or else the complete need would be loaded on the auxiliary system in absence of sunlight. In certain situation the loss of sunlight will last for days in such a case storage of Thermal energy for long term and in abundance is required to be done thus giving rise to new form of storage material than the previous.

ii) Cooling Mode (Mode-C)

This mode is mainly used in warm environmental condition where cool air is to be supplied to the ventilation to maintain the temperature of the space under consideration. This mode uses the combi system as an air-conditioner. The need of this mode is accompanied with plenty of solar radiation which is mainly summer.

As this mode may not be that needed in absence of sunlight and plenty of solar energy will be available in the time of need of this mode so we can very easily bypass the thermal storage section however it is mainly found that we have plenty of spare energy which can be used in different ways like for generation of electricity by the generator. Sometimes it would also be advisable to store this energy for later use but in such a situation thermal storage unit should have high capacity to store energy and that too for quite a long time may be months for usage in HT-Mode. Thus unlike Mode-H, Mode-C can be used alone but it is always advisable to use this with Mode-T. Thus giving rise to another secondary mode that is CT-Mode.

Thermal Storage Mode (Mode-T)

This mode is rarely found to be working in isolation it is always accompanied with either of the other two primary modes. In this mode we would just store the solar energy available for future use. This mode is isolated in only one neither situation when we neither require cooling nor heating for the space.

This mode if found to be isolated for much while then it can be accompanied with a new development of an another mode that is of generation as the energy storage is much limited in certain design so rather than wasting the excess of energy it can be used for generation of electricity which can be used in many ways as needed. As such a situation is very much rare to occur but it is pretty nice to take in to consideration while developing the combi system design. This mode will require least use of the control section and also the use of external supply will be almost zero while this mode is activated by the user.

iii) Other Mode

The primary modes are almost never used alone thus resulting into maximum use of secondary modes. These secondary modes are:

- a) HT-Mode (Heating + Thermal Storage mode).
- b) CT-Mode (Cooling + Thermal Storage mode).
- c) HCT-Mode (Heating + Cooling + Thermal Storage mode).

4. UPGRADATION IN DESIGN

Certain upgradation can be taken into notice while designing the system if they do not affect the outcome of the system in negative sense and turn up to become an add-on or an asset to the system. We would here be discussing four updates each of its own kind that may be about modifying the present design, adding new solar element, adding new mode and section to the system and adding new output.

Firstly modifying the present system we can consider combining the final heat exchanger of both heating and cooling section, reducing the cost and complexity in ventilation system. However this may increase the complexity of the system, complex control unit, system cannot be used in HCT-mode. Complexity arranging auxiliary sources for heating and cooling, limitation of selection of material in cooling section and many other factors will be affected and should be kept in mind.

It is also possible to add a solar dehumidifier for humid type of climate giving an add-on feature to the system. However the dehumidifying factor should be kept in complete control or may result into negative

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impacts such as; an update is not possible for dry climate, it will increase the load on the control unit, complexity in ventilation system would be increased and other factors should be kept in mind [1].

As it was even plotted earlier that a new mode that would be useful where excess of energy is wasted when neither cooling nor heating procedure is carried out and Thermal storage does not have high capacity of storage, a new Mode-G for generation of electricity can be added and this mode can also be used in combination with either of the modes if energy is in access. The generated energy can be used up for different purposes or can be stored and used for self supply and backup power for the system mainly control unit. This sounds quite interesting but excess of such large amount of energy is found almost once in a million situations and this very much increase the cost of the system and its complexity also [2].

Here we have two types of outcome Hot air and Cold air for space heating and cooling system. We can also add water as an outcome to this system that is hot and cold water supply for usage in different purposes. It would be very simple and a great add-on to the system increasing its usability. It can be accomplished by adding just heat exchangers in both the section [11] [7]. A little work would be needed to be done in the control section but that would not be that complex. However this would increase the need of energy resulting into increase of solar collector area and in turn high increase in cost.

5. CONCLUSION

The Theoretical study of the design of a combi system and its different upgradation, modes of working, climate suitability is clear. It is very much sure that a practical statistical assessment of the system will come out to have very fruitful results, which would lead combined Solar systems to a complete new era. It is very alternate and quick solution to the growing need of green energy for space heating and cooling. Even though with so many beneficiaries the system would not be as much affective in certain cases instead individual space cooling and heating system may have a upper hand but still it will be highly effective in future and location where need of both cooling and heating is needed simultaneously or rotationally. Thus system is all set for a statistical and a practical analysis.

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