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Analysis And Comparative Study for Photovoltaic Solar Cooling System Between Two Geographical Regions

G Durga Bhavani[1], Kedaranath M[2]
[1]*(Student, Mechanical Engineering, Godavari Institute of Engineering and Technology, India)*
[2]*(Associate professor, Mechanical Engineering, Godavari Institute of Engineering and Technology, India)*
Corresponding Author: G Durga Bhavani

Abstract: *Our basic motive is to regulate the operating power in solar cooling system. This project presents the results of an experimental investigation carried out to minimize the power consumption of a solar cooling running at various loads. The experiments have been carried out for a total of three loads that is low, medium and high. We carried out speed control by minimizing the input current at multiple speeds with the help of resistors. For high speed, we have connected a couple of resistors in series whereas for medium speed a couple of resistors were connected in parallel and for low speed a single resistor was used. We have used AC motor which is traditional coolers with Permanent Magnet. PM AC motor is highly efficient since no electrical energy is used or losses incurred for developing or maintaining motor's magnetic field.*

The concept of pump is integrated with copper pipe mechanism to the cooler setup. Water is made to flow from a higher potential to lower potential making the grass and pipe wet. Integration copper pipes to the pump increases the cooling effect equivalent to the air-conditioning. We have proposed an alternative methodology to the air-conditioning where we used compressor based approach for cooling system. By this we proposed an alternative low cost air cooling system which saves substantial amount of money spend on air-conditioning and on energy.

Comparison and analysis has been conducted on the power consumption and cooling factors. Extensive study was conducted by comparing PV solar thermal cooling system.

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I. Literature Review

Carol Gauthier et al.,[1997], *Solar Energy*, Vol 60, 333-346 discuss the applications ofa thermodynamic control valve need not be limited to just industrial process heating only. Commercial green houses have very low thermal mass. So it is normal to ventilate excess heat solar heat captured during the day to outside and to supply auxiliary heat from outside during night. Amplitudes of diurnal or nocturnal temperature swings become high during transition between summer and winter months. Either the air flow or working of the fans or blowers needs to be reversed using direction control valves or reversal of air moving machines. In such circumstances thermodynamic control valve can also act as direction reversal valve or direction reversing switch actuator. For example, the above cited paper describes numerical simulation of a soil heat exchanger-storage system for green houses. Here the proposed valve can be used to collect air at the top of the green house during the day and at the ground level during the night.

A.O. Dieng et al., (2001) Renewable and Sustainable Energy Reviews vol. 5, 313–342,states that possibility of using non-polluting materials and to save more than half of the primary energy involved in this sector are obviously the most important characteristics but simplicity, low maintenance and the absence of noisy components are also very important features that make this type of system suitable for numerous other applications such as air-conditioning in cars, trains, bus or food transportation or solar cooling.

Nawaf H. Saeid et al., (2010), Engineering, 2010, 2, 832-840, Parametric study iscarried out in the present article to investigate the unsteady performance of solar energy gain and heat retention of two different integrated-collector-storage systems. The performances of the two systems are evaluated based on the maximum temperature in the system during daytime heating period and nighttime cooling period. For comprehensive study, 24 hours simulations for 3 cases with different wall boundary condition impose on the absorber plate are investigated. The simulation results show that the modified system has better heat retain than the conventional system. Periodic variations of both systems

M. Santamouris et al., (1997), solar energy Vol.60, Nos.3/4, PP.191-197 has discussedthat the passive cooling techniques applied to thermostatically controlled buildings can contribute to reducing their cooling load significantly. Ground and night ventilation technique appears to be most promising among the proposed dissipation technique. This article deals with the development of a integrated method to calculate the energy contribution of ground and night ventilation dissipation technique to the cooling load of thermostatically controlled buildings. The achievements of thermal comfort during summer and reduction of cooling loads by natural means is now considered a first priority for electric utility and consumers.

P. RAMAN et al., (2001),*Solar Energy*Vol. 70, No. 4, pp. 319–329,this paper describesthe development of a solar passive system, which can provide thermal comfort throughout the year in composite climates. In the first phase, passive model 1 comprising two sets of solar chimneys was developed and monitored for its performance for 1 complete calendar year. Based on the feedback and experience, an improved version of model 2 was developed. In model 2 both the tomb wall and sack cloth cooling concepts were incorporated.

II. Introduction

Our project "Solar Cooler" is based on the concept of harvesting solar energy. It is easily interpretable from the name of the project that it is based on the solar energy for satisfying its need of power source. The functionality of Solar Cooler is dissimilar as that of the traditional coolers. The solar energy is harvested and stored in a battery. This battery is in turn connected to the solar cooler for the power source.

The concept of solar cooler sounds good and economical hence almost every class of our society can bear its expenses. The best part is that, it can be used even in rural areas where there will be no supply of electricity.

The main objective is
- Saving power and electricity
- Minimizing season wise servicing
- Varying power consumption at various speeds
- To enable people of those rural areas which do not have electricity supply to have cool air during summer.
- Reduce the maintenance cost by replacing the concept of pump

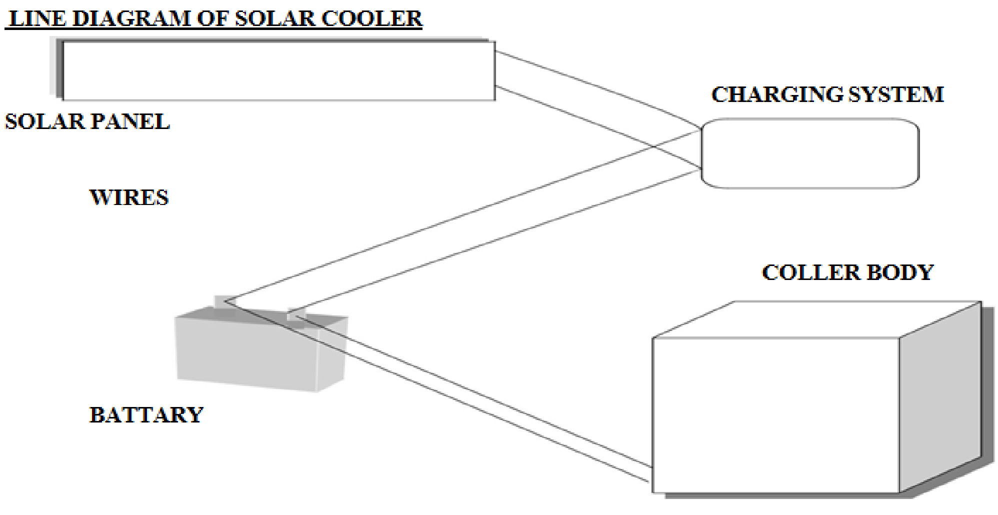


Figure 1: THE SOLAR COOLING SYSTEM

COMPONENT LIST OF A SOLAR COOLER:
- Solar panel
- Battery
- Charge controller
- PM AC motor
- Centrifugal AC pump
- Cooler body

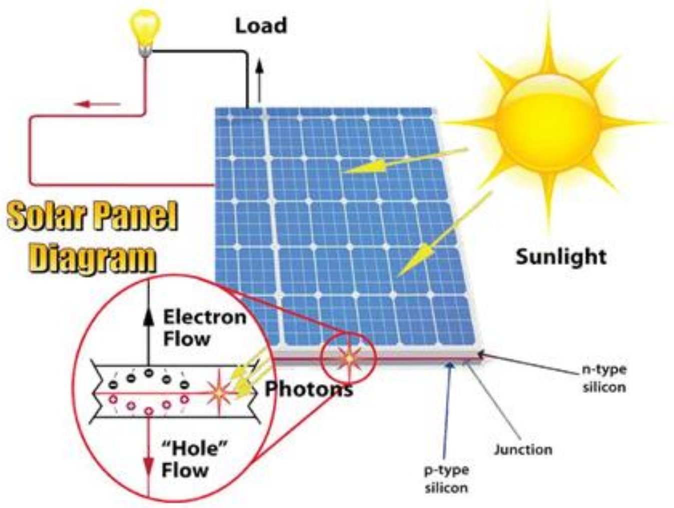


Figure 2: Main Components

III. Design and Simulation

Solar Air-Cooling Design and Simulation

The main objective of this thesis is to analyse and compare the performance of solar thermal air-conditioning technology and solar photovoltaic (PV) air-conditioning technology under the Hyderabad region´s climate conditions and cooling load profiles. And to compensate the cooling power production by these technology to TSFH load demands for each case (Secundrabad-TSFH, Hyderabad-TSFH).

In order to investigate the above stated objective, the following three scenarios are designed and simulated for each building: Secundrabad-TSFH and Hyderabad-TSFH, as in this chapter the design procedure, simulation and methodology for each scenario are explained. Where the simulation of cooling production by each scenario is carried out by Matlab-Simulink, where the solar radiation on tilted surface has been calculated by using TRNSYS software. That based on the TSFH cooling demand profile which simulated by TRNSYS software for each case.

Matlab Simulation Environments

Simulations are powerful tools for process design, for study of new processes, and for understanding how existing systems function and might be improved. Numerical simulation offers the possibility to virtually study physical solar air-conditioning systems. Simulation is then the most adapted method to investigate the performance of the cooling profile of the system's output. There are different dynamic simulation software's available for simulating the air-conditioning system and calculating its cooling products. To mention, SPARK, Energy Plus, EES, Easy Cool, TRNSYS and INSE, MATLAB.

In this study for the Matlab-Simulink simulation in order to calculate the cooling production by each scenario for each case (Secundrabad-TSFH and Hyderabad-TSFH).Two time series of data with 15 minute time steps are required as input data, in almost every simulation of cooling production for each scenario: the first type of the time series contains the global solar radiation on a tilted surface and the outside ambient air temperature. The second type of the time series contains the cooling load demand of a TSFH which is obtained from the TRNSYS simulation. However, the Secundrabad and Hyderabad weather data files which received in this study include the solar radiation data on horizontal surface. Additionally, Secundrabad data file is in TMYE format which is unreadable by this program.

Thus the solar radiation on tilted surface has been calculated by using TRNSYS 16 before starting with the cooling production simulation in Matlab-Simulink.Where the tilt angle is considered to be equal to the latitude of the location (23°54'N for Secunderabad-TSFH and 29°31'N for Hyderabad-TSFH).

Solar PV Air -Conditioning Scenarios

As per the objective of this study, two scenarios of the PV air-conditioning systems have been investigated: PV air-conditioning without storage (see Figure 3) and PV air-conditioning with storage (see Figure 4). These scenarios are designed for each case, Secunderabad-TSFH and Hyderabad-TSFH. This section discusses the system components and designs followed by the system simulations and methodology

System Components and Design

Figure 3 and Figure 4 show the two scenarios based on a PV-driven compressed chiller. The PV air-conditioning without a storage scenario consists of a PV–module, inverter, a compressed chiller and a system distribution. The system set up of a PV air-conditioning with storage is similar to the first scenario, but it additionally has a storage (battery) system and a charge controller.The PV module converts solar radiation into electric power as direct current (DC). The solar charge controller regulates the voltage and the current which comes from the PV module into the battery. This prevents from the overcharging of the battery and increases the battery life.

The inverter converts DC into alternating current (AC) which is needed to drive the compressed chiller. The battery stores the excess energy for supplying the compressed chiller when there is no enough solar radiation to cover the cooling demand. The compressed chiller converts the AC power to the cold air. The compressed chiller is supplied as a back-up with an electric AC power from the grid, when there is not enough DC power from the PV-array and the battery bank, especially at night, evening and morning of the day when there is no enough solar radiation to drive the compressed chiller.

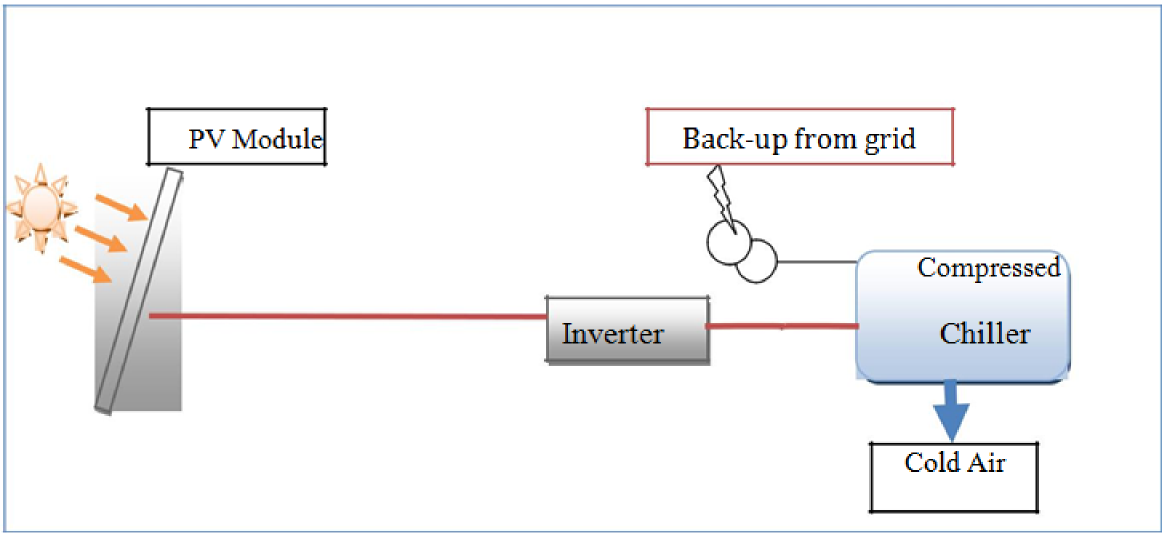


Figure 3: Schematic flow diagram for solar PV air-conditioning without storage.

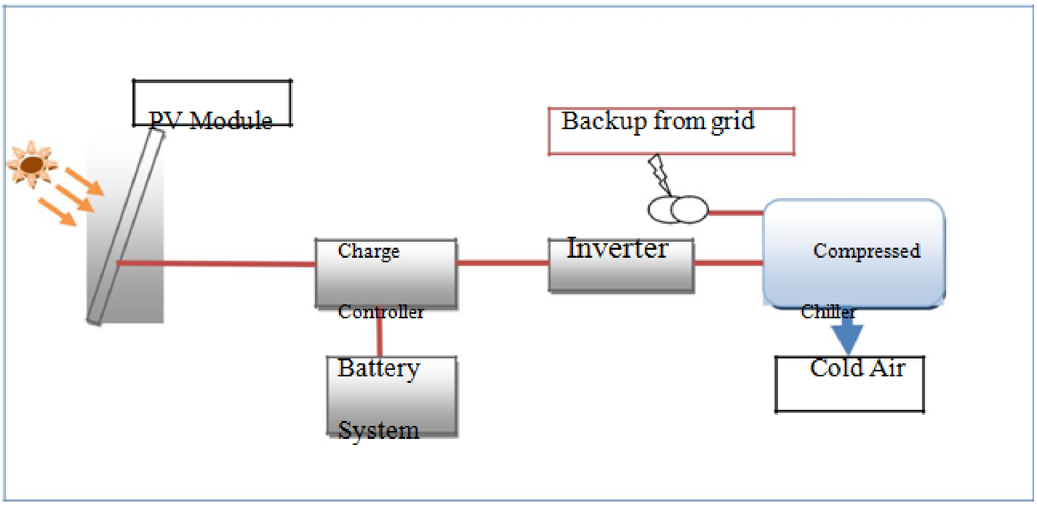


Figure 4: Schematic flow diagram for solar PV air-conditioning with storage.

IV. Simulation Results and Analysis

This chapter includes the simulation system scenarios results. The results are analysed for each scenario. Then, the comparison between the solar thermal air-conditioning with storage scenario and a solar PV-air-conditioning scenarios with and without storage scenarios is done. Eventually, conclusions and the further work are delineated.

So in this study the expressions, '*Cooling production energy/power'* means the cooling energy/power which is produced by any air-conditioning system scenario as without storage. '*Direct cooling compensation energy/power'* means the cooling energy/power which compensate part from the cooling demand by the air-conditioning system scenario as without storage. *'Storage compensation'* means the cooling energy which compensates part from the cooling demand by the contribution of the storage system in the air-conditioning system scenario. '*External back-up cooling energy/power'* means the cooling energy/power which produced by the contribution of the backup system of the solar air-conditioning system from the grid electricity in each scenario, in order compensate the residual cooling demand, (the electric back-up heater in thermal air-conditioning scenario, direct grid connection with the compressed chiller in PV air-conditioning scenarios).

Solar Photovoltaic (PV) Air-conditioning Scenarios

The simulation results and analysis of the results for the two PV air-conditioning system scenarios, without and with storage (battery) has been discussed for the Secundrabad-TSFH and Hyderabad-TSFH cases. The battery was designed to compensate the cooling load demands. Firstly, the influence of the cooling production load by the solar PV air-conditioning system without (battery) scenario is diagrammed. Then it is followed by the excess of cooling production and the external back-up cooling load results analysis, in order to explain the storage which is designed for the solar air-conditioning system with battery scenario. Finally, analysis of the results is made for annual cooling energy products to compensate the cooling energy demands of the two cases, Hyderabad-TSFH and Secundrabad-TSFH. That's for each scenario, PV solar air-conditioning system without battery and PV solar air- conditioning with battery.

The Influence of a Direct Cooling production
Weekly Analysis:

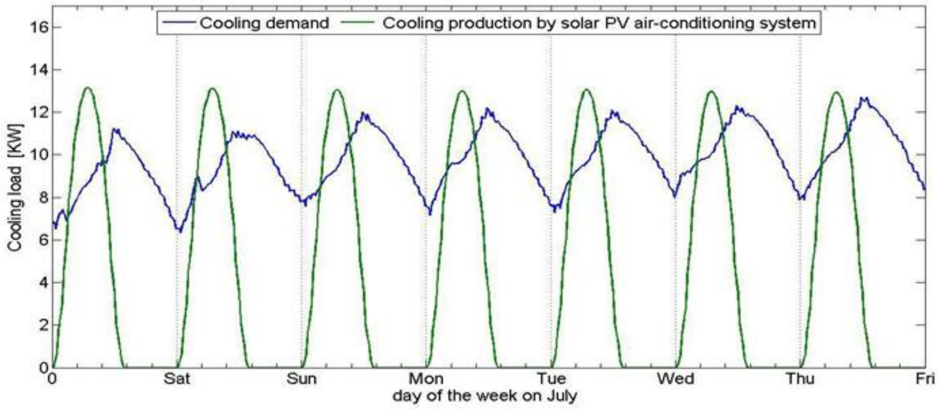


Figure 5: Solar-PV air-conditioning cooling production in Summer week for Secunderabad-TSFH.

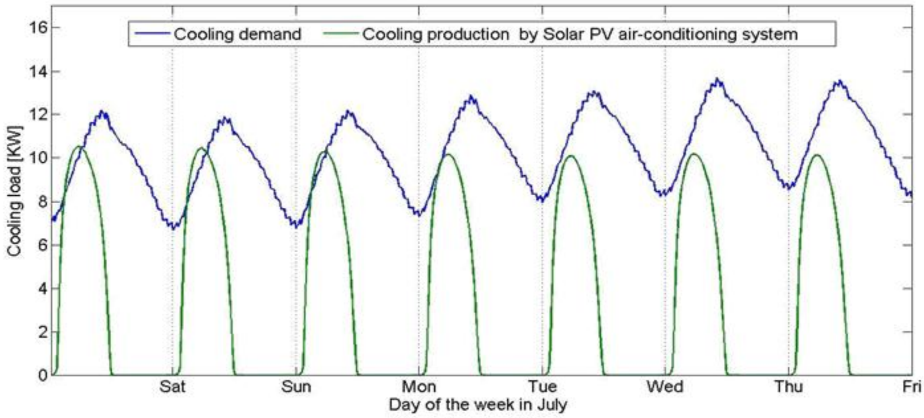


Figure 6: Solar-PV air-conditioning cooling production in Summer week for Hyderabad-TSFH.

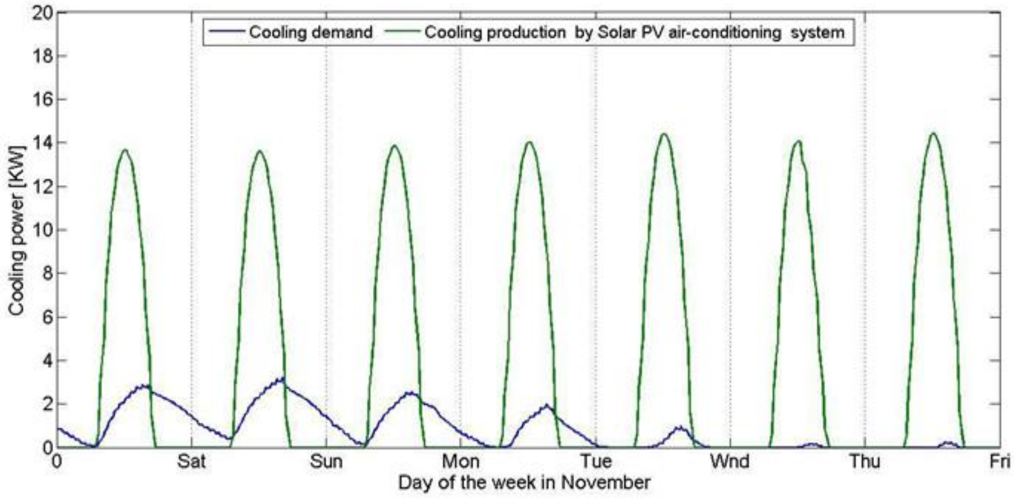


Figure 7: Solar PV air-conditioning cooling production in winter week for Secunderabad-TSFH.

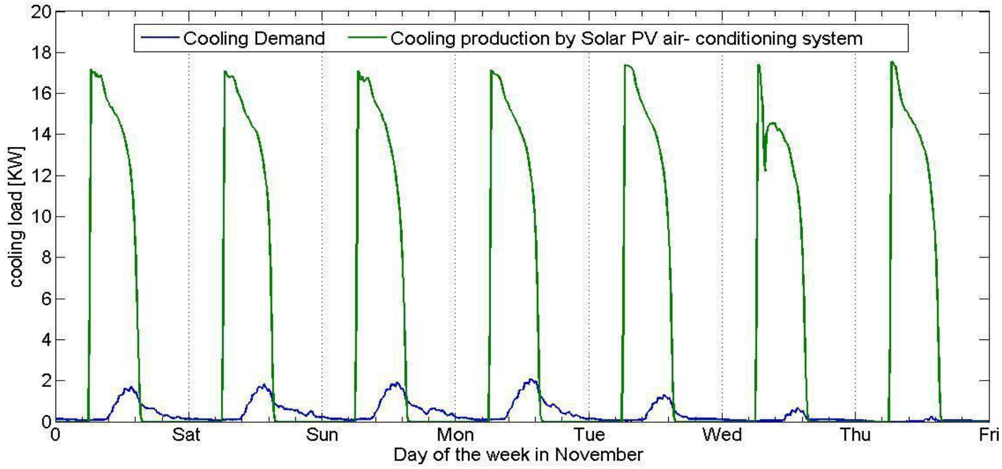


Figure 8: Solar PV air-conditioning cooling production in winter week for Hyderabad-TSFH.

In summer (see Figure 5 and Figure 6), in general, Secunderabad-TSFH has excess cooling production than the cooling demands compared with the case of Hyderabad-TSFH by which there is a little of excess cooling production. This due to a bigger solar radiation in Secunderabad city than in Hyderabad city and vice versa of cooling demand. There is a bigger cooling demand in Hyderabad than in Secunderabad especially in summer

As shown in Figure 5and Figure 6, most of the external back-up cooling load is needed during the evening, the night and in the morning due to a high cooling load demand in these periods of the day.

In Hyderabad-TSFH case, the curve starts increasing in the morning with a high slope and reaches its peak at noon and in turn it decreases to reach zero in the evening, compared with the Secundrabad-TSFH case. The reason is the increment in the solar radiation which is higher than Hyderabad during the day time and this increases the thermal heat effect on the PV module’s efficiency and reduces the module electric power output. In addition, the presence of a higher ground solar reflection and diffusion in Hyderabad city than in Secundrabad city could lead to an increment in power output from the PV module.

Monthly Analysis

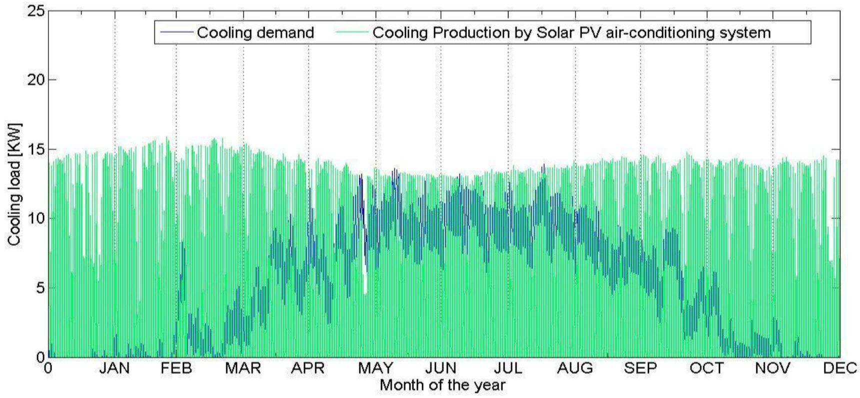


Figure 9: PV air-conditioning cooling production along the year for Secunderabad TSFH.

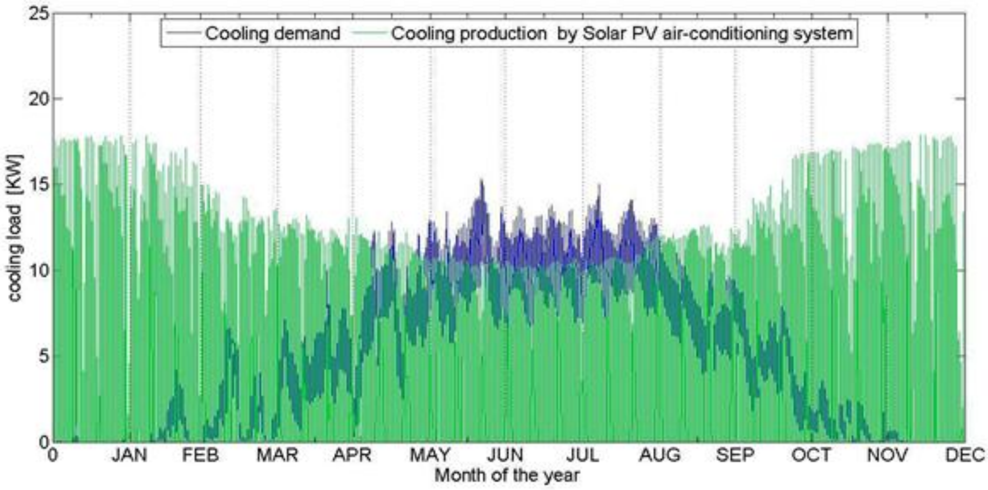


Figure 10: PV air-conditioning cooling production along the year for Hyderabad-TSFH.

The cooling production covers almost entirely the maximum peak of the cooling load demand for Secunderabad-TSFH especially in the summer. On the contrary, for the case of Hyderabad-TSFH, the cooling production is lower than the maximum peak of the cooling load consumption by 3 to 4 kW for the reason that there is a higher solar radiation in Secundrabad than in Hyderabad. Besides, Hyderabad-TSFH has higher peak load demand in summer than Secundrabad.

For both cases, the cooling production in winter is higher than in summer. This in turn means, operation module is more efficient in winter than in summer.The ambient air temperature in winter is lower than in summer for both cases. This reduces the thermal effect on the PV module by improving the heat transfer rate from the PV module to the ambient air with the help of the temperature difference between the module and the air which is higher in winter than in summer. This leads to increase the module efficiency and electric power output.

Excess of Cooling Production and External Back-up Cooling for a Battery Design

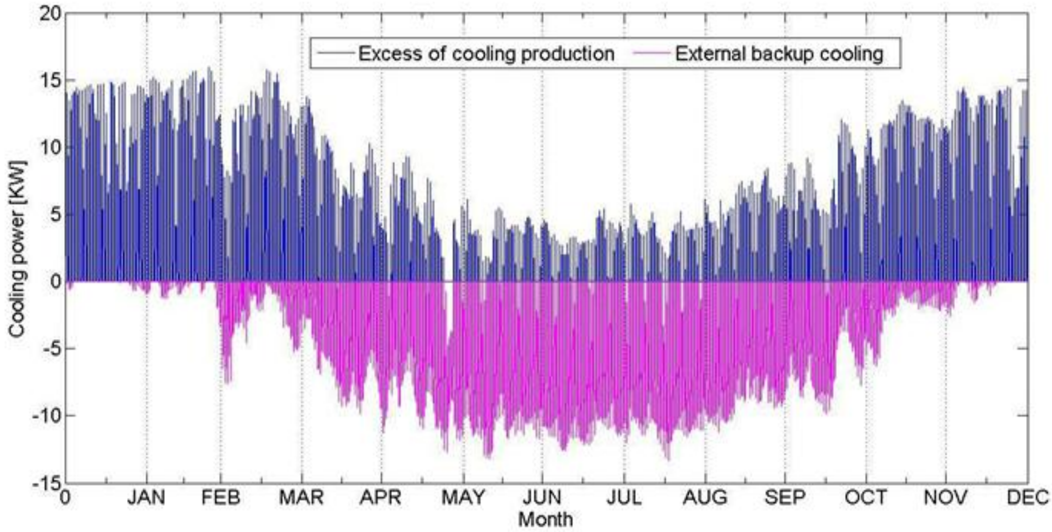


Figure 11: PV air-conditioning without storage scenario, Excess cooling production and external back-up cooling loads for Secunderabad-TSFH.

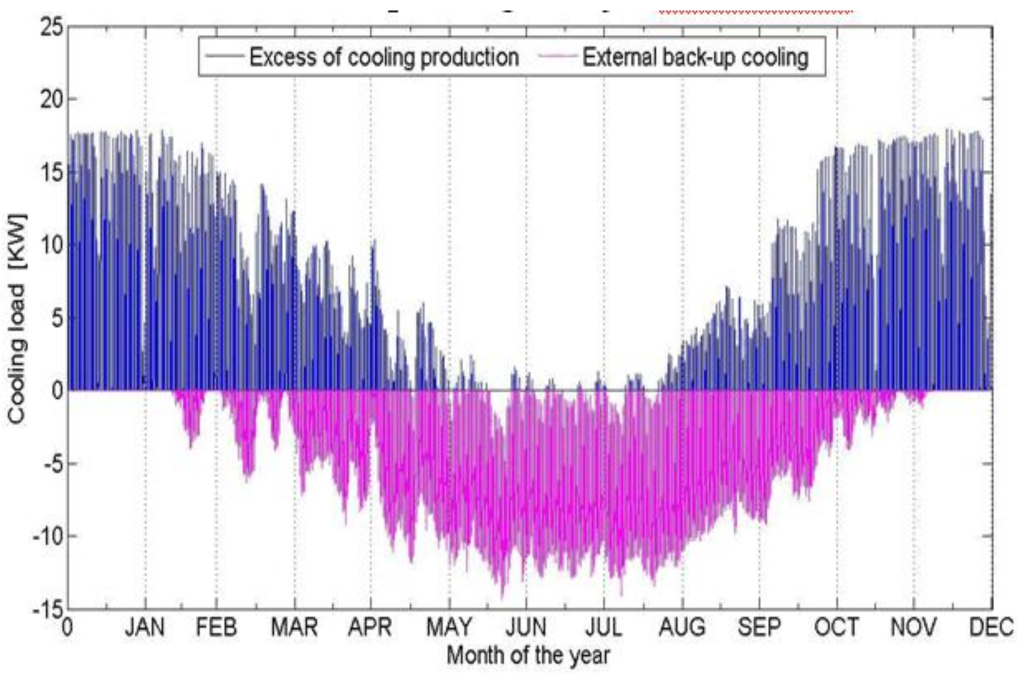


Figure 12: PV air-conditioning without storage scenario, Excess cooling production and external back-up cooling loads for Hyderabad-TSFH

As shown in Figure 11 and 12, Secundrabad-TSFH has an excess of cooling production along the year but in Hyderabad–TSFH case, there is a little excess of cooling production in summer season especially in June, July and August. That's due to a higher solar radiation in Secundrabad and a higher cooling demand in Hyderabad-TSFH in these periods

Approximately there is no external back-up cooling load needed in January, February and December and there is a significant excess cooling production load. In April and October, the excess cooling production is almost equal to the external back-up cooling load for both cases.

IV. Results and Analysis for Solar Thermal Air-conditioning

The Influence of Cooling Production

Weekly Analysis :

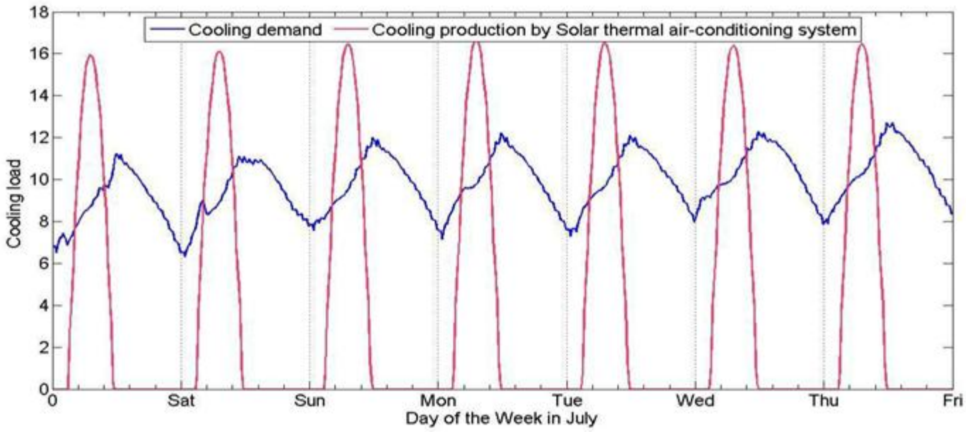


Figure 13: Solar thermal air-conditioning cooling production in summer week for Secundrabad-TSFH.

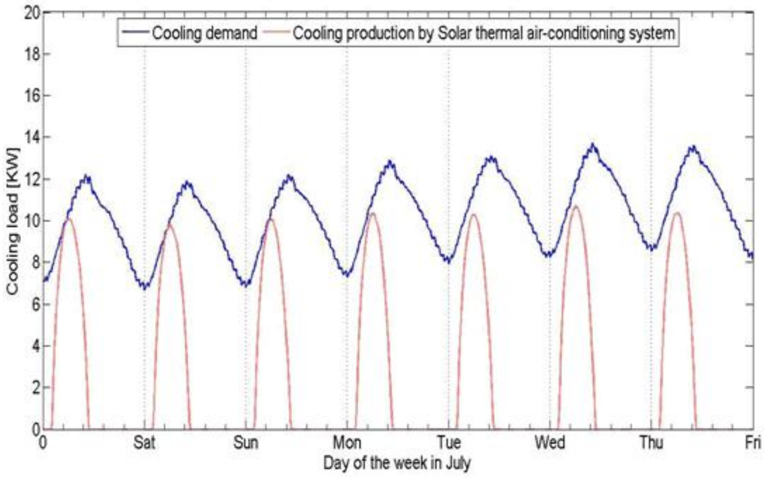


Figure 14: Solar thermal air-conditioning cooling production in summer week for Hyderabad-TSFH.

In summer season, Figure 13 and Figure 14 in Secundrabad case display that there are excess of cooling production than the cooling demand. On the contrary, for Hyderabad-TSFH case, there is a little excess of cooling production. In addition, it has a higher mismatching with cooling load demand due to higher solar radiation in Secundrabad city than Hyderabad city. And it has a higher heat losses from the solar collector to the ambient air.

Monthly Analysis:

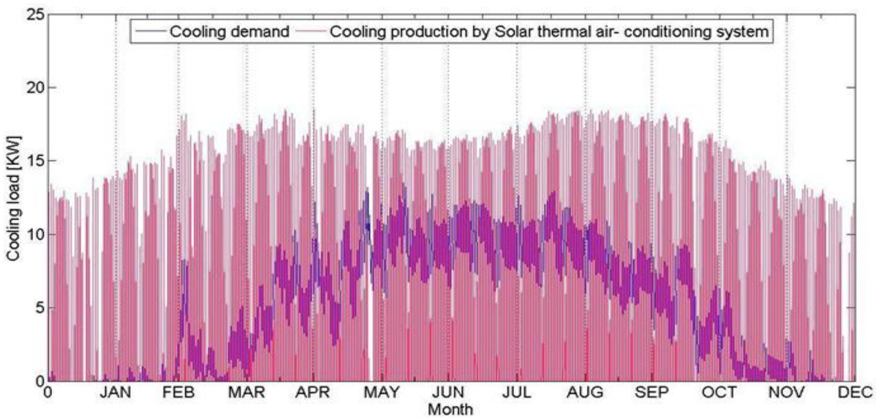


Figure 15: Solar thermal air-conditioning cooling production along the year for Secundrabad-TSFH.

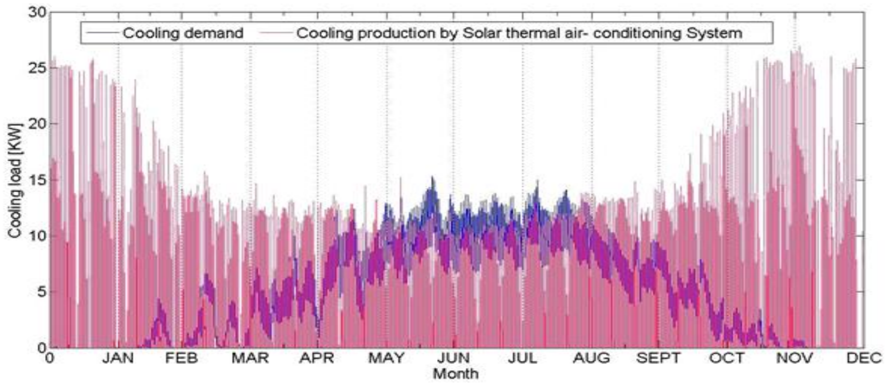


Figure 16: Solar thermal air-conditioning cooling production along the year for Hyderabad-TSFH.

Figure 15 and Figure 16 give an overview of the cooling production throughout the year by the solar thermal air-conditioning systems as without storage for Secundrabad-TSFH and Hyderabad-TSFH respectively.

These graphs show that in Secundrabad-TSFH case, there is a higher cooling production along the year than the cooling load demand in Hyderabad-TSFH.

In the case of Hyderabad, the situation is different in the summer season. The cooling production rises up to near the maximum peak cooling load demand. In other words, there is a little excess of cooling production. Both cases have a high overloaded cooling production in winter season as a waste of energy especially in January and December because there is no cooling demand.

Thermal Air-conditioningVersus PV Air-conditioning
Weekly Performance:

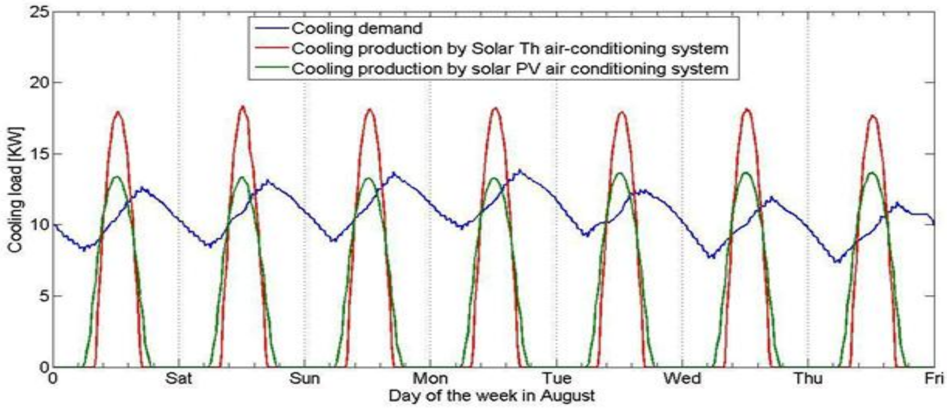


Figure 17: PV air-conditioning versus solar thermal air-conditioning, cooling production performance in Summer Week for Secundrabad-TSFH.

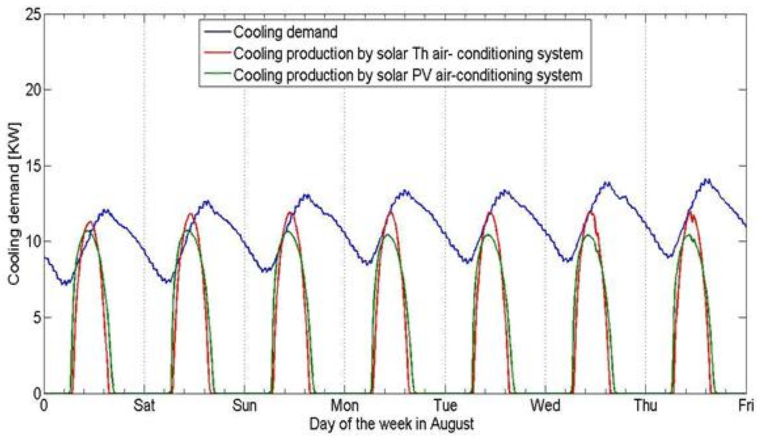


Figure 18: PV air-conditioning versus solar thermal air-conditioning, cooling production performance in Summer Week for Hyderabad-TSFH.

The daily cooling production along the week by the thermal air-conditioning scenarios has a higher peak curve than the PV air-conditioning scenarios. In addition, the excess cooling production which is above the cooling load demand curve of the solar thermal air-conditioning scenario is higher than the curve for the solar PV air-conditioning scenario. That could lead us to say that the storage system for the thermal air-conditioning scenario is more important and efficient than the PV scenarios especially in summer for Secundrabad-TSFH

Annual Cooling Compensation Energy Percentage

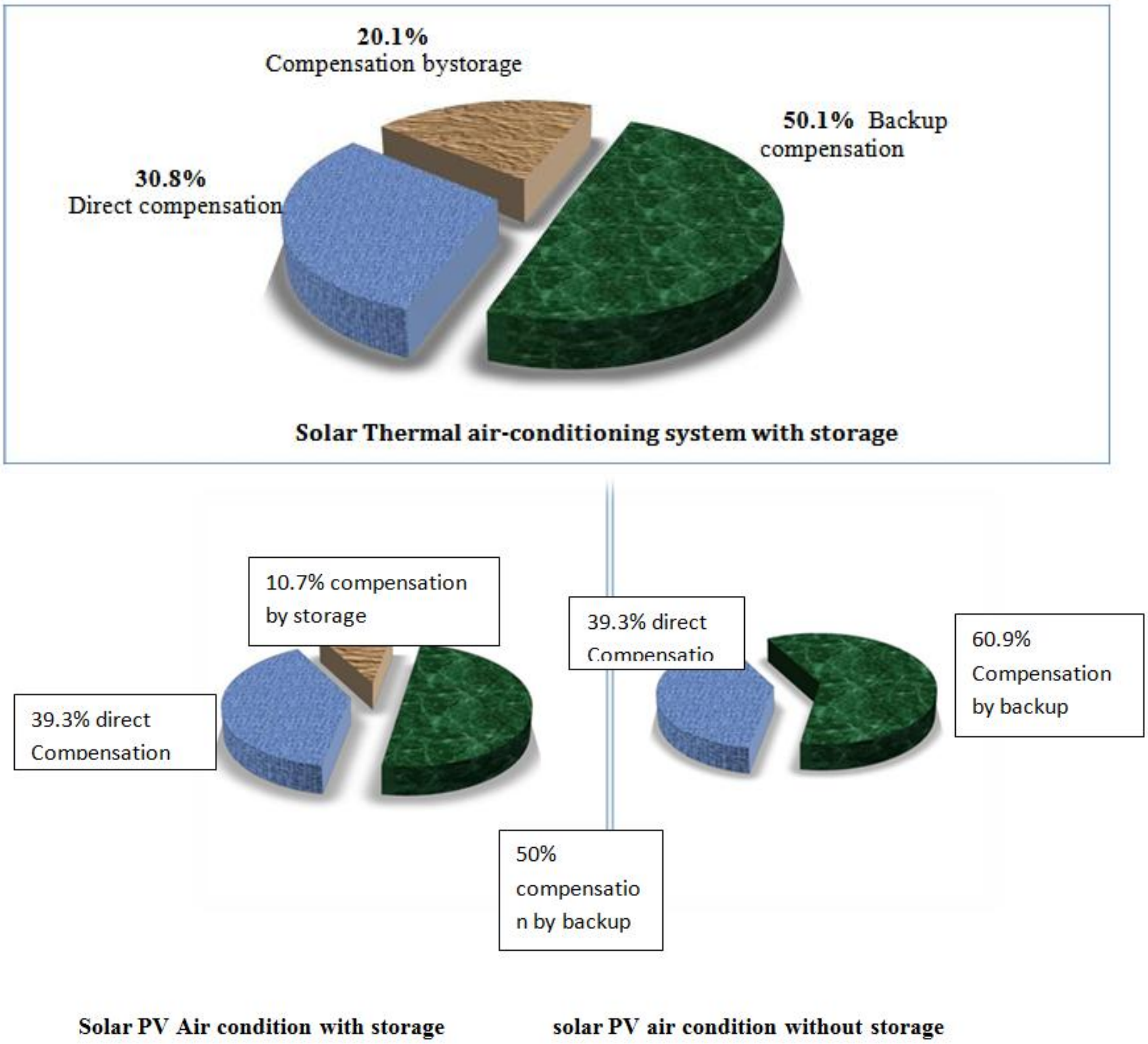
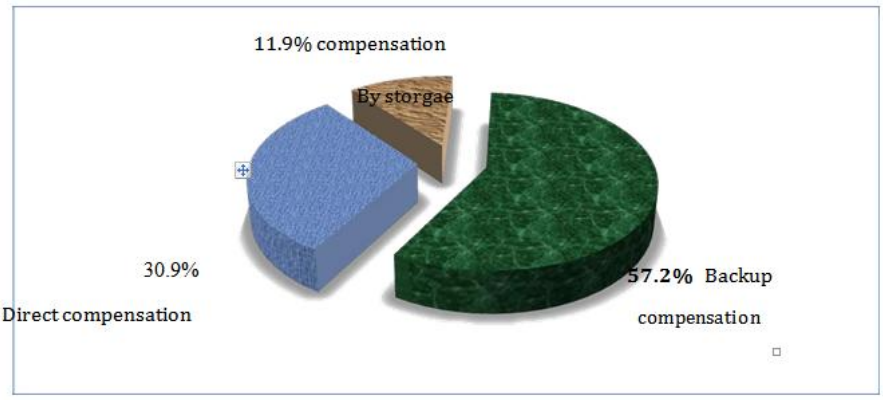
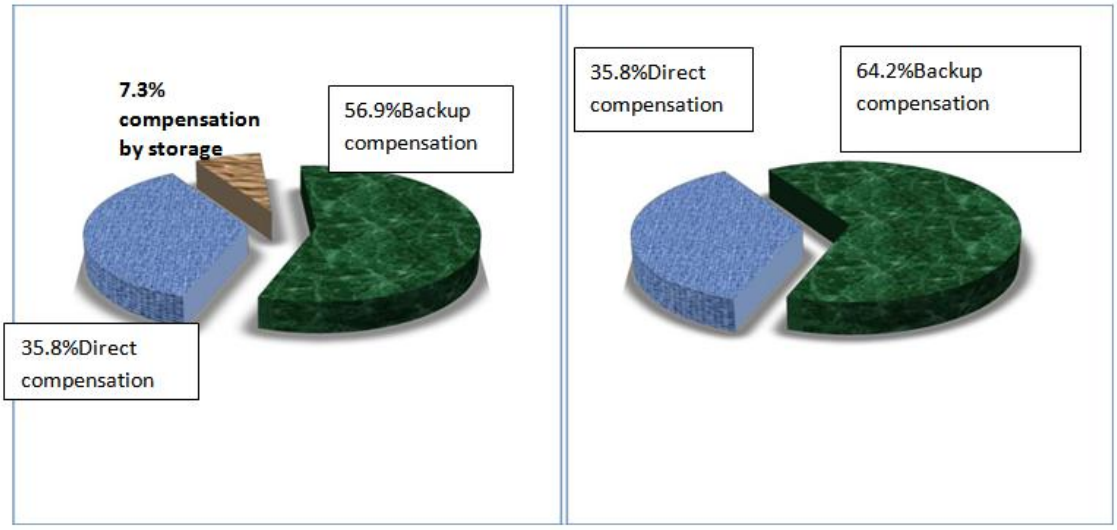


Figure 19: Percentage of cooling Energy compensation by the three scenarios for Secundrabad-TSFH.



Solar thermal air-conditioning system with storage



Solar PVair-conditioning system with storage

Solar PV air-conditioning System without storage

Figure 20: percentage of cooling Energy compensation by the three scenarios for Hyderabad-TSFH.

The above mentioned percentages are higher than the direct cooling compensation percentage by the thermal air-conditioning scenario, 30.8 % and 30.9 % for the Secundrabad-TSFH and for the Hyderabad-TSFH cases respectively.

Yearly, the total percentage cooling energy compensation by direct and storage in solar thermal air-conditioning system with storage scenario is 50.9 % and 42.8 % for Secundrabad-TSFH case and for the Hyderabad-TSFH case respectively. The total compensation by PV air-conditioning with storage scenario, 50 % and 43.1 % are respectively for Secundrabad-TSFH and for Hyderabad-TSFH cases. From these results, the percentage difference between the two scenarios does not exceed 1 % in both cases(Secundrabad-TSFH and Hyderabad-TSFH)and in turn there is no big difference between the two scenarios based on the cooling demand

V. Conclusions and Future Research

Conclusions

The traditional air-conditioning is one of the main consumers of electrical energy today in the hot geographical region. However, this region has a huge solar energy potential with an average of 2,334 kWh/m2/year and with average daily sunlight exceeding 8.8 hours. Solar air-conditioning technology is definitely a solution to cover the cooling demand for this hot and sunny region. The present study analyzes and compares the solar thermal air-conditioning technology and the photovoltaic air-conditioning technology under two different location (Secundrabad, India and Hyderabad, India). That is based on the cooling demand for the reference building (TSFH) in these regions.

Cooling load demands:

The thermal load demands for the reference building (TSFH) in each location were determined by TRNSYS software. The following points can be concluded:

The maximum cooling load demand during the summer season are: 13.9 kW and 15.3 kW for Secundrabad-TSFH and Hyderabad-TSFH respectively. For both cases, the cooling demand occurs for ten months while the heating demand is only required in two months. The annual cooling energy demands are: 44,330 kWh/year and 43,490 kWh/year for the Secundrabad-TSFH and the Hyderabad-TSFH respectively which represents 97.5 % and 96.3 % of the total annual energy consumption (heating and cooling). That shows the importance of cooling compared to heating in these locations.

The performance of the cooling load during a summer day shows a huge cooling demand (approximately 8 to 10 kW) during the night. Therefore, it is necessary to cover the night cooling demand as well as the day time in these regions.

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