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# APPRAISAL OF A SOLAR POWERED AIR CONDITIONING SYSTEM

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## ABSTRACT

*The availability of solar radiation in phase with the seasonal as well as hourly cooling load profiles in most of the office buildings in the Mediterranean region, in addition to the large share of primary energy consumed for air-conditioning applications in office buildings create a high motivation for the utilization of solar cooling technology for such type of buildings. A*

## INTRODUCTION

The availability of solar radiation in phase with the seasonal as well as hourly cooling load profiles in most of the office buildings in the Mediterranean region, in addition to the large share of primary energy consumed for air-conditioning applications in office buildings, creates a high motivation for the utilization of solar cooling technology for such type of buildings. Within the framework of the EC co-funded project

SOLERA, a demonstration solar heating and cooling plant has been installed at an office building and its performance has been monitored during the period 2010 – 2011. The system is located in North Italy and covers the heating and cooling demand of 172 m2 floor area. The monitoring data have been collected according to the monitoring procedure defined with the IEA SHC Task 38 [1]. This monitoring procedure can be conducted at three different levels of detail:

(i) Basic information on primary energy ratio and costs

(ii) Simple analysis of the solar energ y source management
(iii) Advanced monitoring procedure

In this work, the third level of detail has been adopted. In the following, after presenting system scheme and operation, the outcome of the monitoring campaign 2011 is presented and discussed.

**Nomenclature**

$\eta_{col}$ Solar collector efficiency
$\eta_{tank}$ Storage tank efficiency
$COP_{th}$ Chiller thermal coefficient of performance
$COP_{el}$ Solar cooling electrical coefficient of performance
PER System primary energy ratio
$f_{sav,SHC}$ Fractional energy savings in solar heating and cooling

**System description**

The solar cooling and heating plant simplified scheme is shown in Figure 1. The scheme presents the main system components:

- Flate plate collectors of 61.6m² absorber area
- Hot water buffer storage (5000 l).
- Reversible heat pump as a backup for heating.
- Single effect Lithium-bromide absorption chiller (Yazaki WFC-SC5)

*solar heating and cooling system for an office building in Italy has been designed, installed and monitored within the framework of the EC co-funded project SOLERA aiming at developing highly integrated solar thermal heating and cooling system that is able to achieve a high solar fraction both for the heating and cooling seasons. The analysis of the system performance during 2011 is presented in this paper, with main focus on electricity consumption during summer. The analysis has been carried out according to the monitoring procedure developed within the frame of the IEA SHC Task 38.*

***Keywords:** Solar assisted air-conditioning; solar cooling; absorption; performance assessment.*



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with 17.6 kW cooling power and COP of 0.7 at nominal operation temperatures.

- Wet cooling tower of the company Evapco (ICT 3-63) with 42.7KW nominal power.
- Cold water storage (1000 l).
- Reversible heat pump as a backup for heating and cooling.

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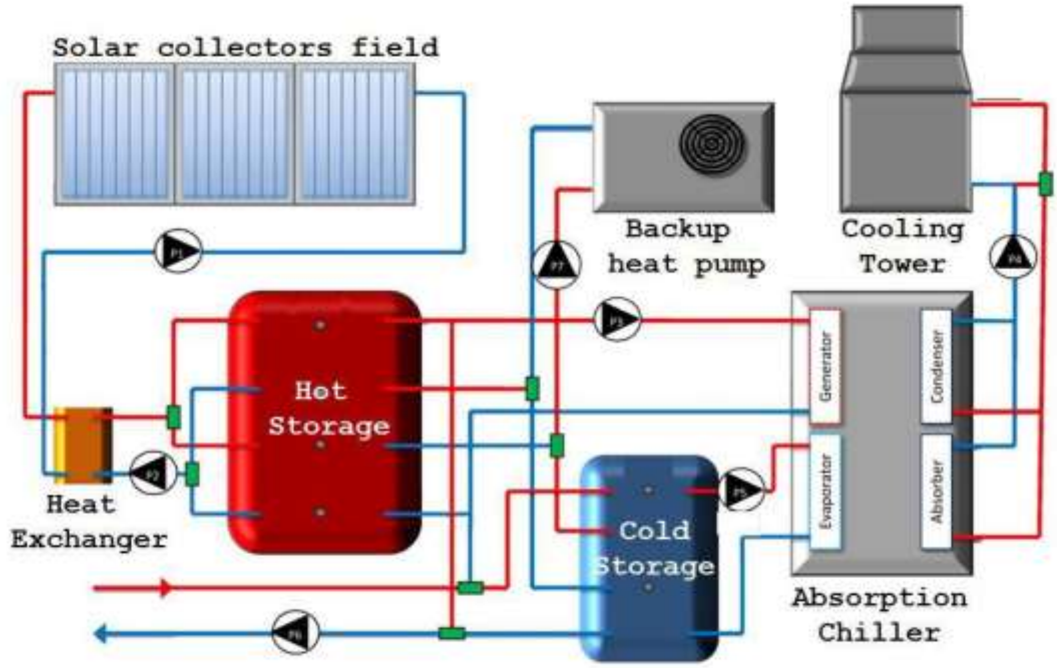


Fig. 1. Simplified scheme of the solar heating and cooling system, presenting the solar collectors, the absorption chiller, the cooling tower, the hot and cold storages and the backup heat pump

During the winter season, the heat collected by the solar collectors is delivered to the hot storage. If the temperature of the hot storage is below the required temperature for the distribution system (40 - 45 °C) then the heat pump delivers heat to the hot storage to satisfy the system required temperature.

During the summer period, the absorption chiller starts as soon as the temperature at the top of the hot storage is above a threshold value. The chiller has an inlet working temperature range between 70 - 95 °C, with a nominal input temperature of 88°/83°C in/out. If the


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temperature at the top of the hot storage is below the set value, the reversible heat pump working in cooling mode is operated.

The absorption chiller is connected to three circuits: the first at high temperature connecting the absorption chiller's generator with the top of the hot storage, the second is at low temperature connecting the evaporator with the cold storage, and the last is connecting both the absorber and the condenser with the cooling tower.

**System performance figures**

The monthly average system performance figures are reported in Table 1. The exact definition of each performance figure can be found in the IEA SHC Task 38 related literature [1] and shall not be reported here. The solar collector efficiency is within the expected range for all months, considering the relatively high temperature requested in input at the generator during summer. The tank efficiency is high in the peak heating and cooling months and, as expected, drops significantly when the building loads are low. The thermal COP of the chiller is below the nominal value of 0.7 and shows the lowest values when the load is low; this is can be due to frequent cycling and cooling power generation at temperatures lower than 7 °C. Cycling badly affects also the solar cooling electrical COP, the primary energy ratio and fractional savings during the cooling months, whereas the large values of primary energy ratio and fractional savings during the end of winter are justified by the relative abundance of solar thermal heat.

Table 1. System performance figures (2011)

| season | month | $\eta_{col}$ | $\eta_{tank}$ | $COP_{th}$ | $COP_{el}$ | PER | fsav,SHC |
|---|---|---|---|---|---|---|---|
| | feb | 26.4% | 87.3% | | | 0.80 | 4.2% |
| | mar | 31.9% | 79.2% | | | 0.87 | 18.6% |
| winter | | | | | | | |
| | apr | 36.3% | 35.8% | | | 2.33 | 69.0% |
| | may | 37.6% | 11.8% | | | 2.79 | 74.2% |
| | may | 25.6% | 52.3% | 0.39 | 2.91 | 1.06 | -3.0% |
| | jun | 27.9% | 55.4% | 0.52 | 3.76 | 1.16 | 7.8% |
| summer | jul | 32.2% | 64.5% | 0.57 | 4.54 | 1.32 | 20.2% |
| | aug | 37.9% | 74.6% | 0.57 | 4.41 | 1.36 | 22.6% |

| | | | | | | |
|---|---|---|---|---|---|---|
| sep | 32.7% | 61.5% | 0.55 | 4.1 | 1.21 | 11.4% |

The electrical consumption during summer is further investigated during August (see Fig. 2). The consumption due to the generator pump is quite high if compared to that of the solar loop pumps and that of the evaporator pump. This suggests that a better design of the circuit and the generator heat exchanger could greatly enhance the electrical COP of the solar system. Moreover, the cooling tower (pump and fan) and evaporator pump are running also when the absorption chiller is not producing cool power (i.e., standby) and the generator pump is off. In order to evaluate how often this situation occurs, the electricity consumptions of cooling tower and evaporation pump have been aggregated according to the chiller operation modes, i.e. mode "on" and mode "standby".

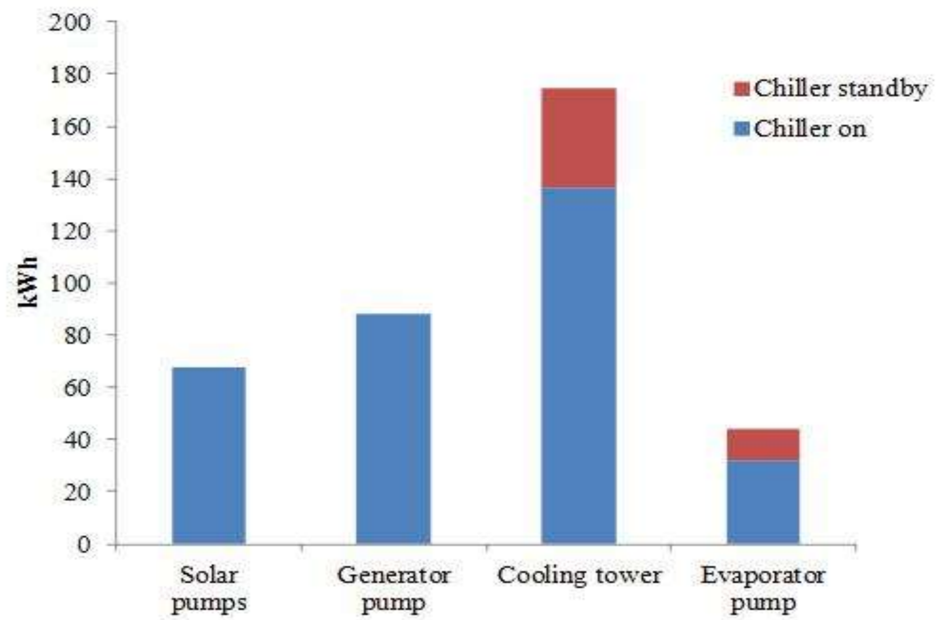


Fig. 2. Solar system electricity consumption (August 2011)

Ven in the peak summer months, when the number of operating hours of the chiller is maximum, a significant amount of electricity is consumed by the cooling tower and the absorption chiller evaporator pump during the chiller standby period. This fact suggests that the control strategy could be improved by better integrating the controllers of the different subsystems within the overall plant control. By lowering the power consumption during the chiller standby mode, the electrical COP of the solar system could be raised from 4.41 to 5.11.

## Conclusion

For the considered solar heating and cooling system, the monitoring data for 2011 have been presented. The main results of the performance figures calculation are given in this paper based on the criteria defined within the IEA SHC Task 38. The main conclusions obtained regarding the performance analysis carried out are: the performance of the collectors are as expected, with monthly values between 30% to 40%; the hot tank efficiency value is sufficiently high only during the peak heating and cooling months; the thermal COP of the absorption chiller is stable during the whole summer period with an average value of 0.55; the average solar electrical COP for the working period is almost 4.0 which is not an optimal value, the main reasons being due to high standby losses associated to the cooling tower circuit; the primary energy ratio and the fractional savings in heating and cooling are attractive at the end of the winter and during the peak months of summer. In the future, higher savings could be achieved by better controlling the cooling tower circuit and absorption chiller evaporation pump when the chiller is in standby mode.

## References

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