SOLAR DISTRICT HEATING OF VARESE
RESULTS AND EXPERIENCES FROM THE FIRST YEAR OF OPERATION

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Abstract – The installation of the first Solar District Heating in Italy was carried out at beginning 2015, and the plant started operating on May 13th.
Beyond a description of the plant, pointing up the peculiarity of the hydraulic diagram with pre-heating of replenishment water, and the key role of programmable controller and remote monitoring the aim of this work is to present the results of the first year of operation, comparing the real operation paramethers and the performances with the planned values.
Furthermore, costs for O&M during the first year are analized and quantified, including consequences of stagnation.
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1. CHRONOLOGY

The construction of the first italian solar thermal plant for district heating started at the end of November 2014, laying underground pipes for the connection of the solar field. In January 2015 64 collectors where mounted on the ground, but the completion of the plant has been conditioned by the construction work of the building “Magazzino”, intended to accommodate 9 additional solar collectors on the roof, and the pumping and heat exchange unit and the PLC control system inside. On May 13th 2015 the system, completed, started operating.
This article is an analysis of the performance and operation of the solar system, in the period between 13 May 2015 and 12 May 2016.

Fig. 1 – The solar district heating of Varese

2. FEATURES OF THE SOLAR THERMAL SYSTEM AND INTEGRATION IN THE DISTRICT HEATING

The solar field is made of 73 Arcon-Sunmark HT-HEATBoost single glazed collectors, totalizing 990 m2 gross area and 920 m^2 aperture. The decision not to exceed 1000 m^2 gross area was dictated by the maximum size allowed to be eligible for the subsidy "Conto Energia Termico."
The district heating network of Varese was built in the early 90’s and it has an extension of about 16 km. Some leakages in the network are accepted as physiological. The high density of buildings in the area makes the repair of small leakages not economical.
Such leakages require a corresponding replenishment of water, which imply also an energy need to heat the water from 10 ° C to the network temperature (65-90°C).
This energy need is a very small amount within the energy balance of the district heating (approx. 0,2%), but they are relevant compared to the expected contribution from the solar system.
A peculiarity of this solar district heating is the fact to provide heat either directly to the district heating network (getting it in the thermal storage already included in the cyrcle), and for the preheating of the replenishment water.
This enables to lower the average return temperature to the solar heat exchanger and, consequently, to increase the efficiency of the solar thermal system.

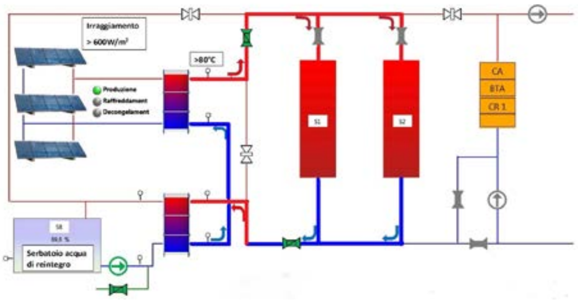


Fig. 2 – Hydraulic scheme of the solar system, including the pre-heating of replenishment water

3. THE KEY ROLE OF PLC CONTROL SYSTEM

Despite of the size below 1000 m^2, the plant is equipped with a sophisticated PLC control system, typical of largest solar installations.

Main benefits are:

1. High stability in the temperatrure output, thanks to the speed controlled pumps, driven in consequence of the instantly measured solar radiation.
2. Large number of data measured and logged, enabling full comprehension and optimization of the system dynamics.
3. Remote monitoring, that enables you to immediately assess any anomalies and act timely.
4. Wide possibility to improve and optimize the control logic, also according to registered patterns and experiences.

Thanks to the fully automatic control, the solar heating system has been working, since May 13 2015 up to now in a continuous way and with no need of manual intervention. The only one exception happened on August 17th 2015, when an interruption of power supply caused stagnation, and the solar system needed to be restarted manually, as foreseen in this rare eventuality.

4. INSTANT PERFORMANCES

On May 27th 2015, the performance test was carried out, according to fact sheet 3.3 of solar district heating guidelines. The performance factors of the collectors were taken from the solar keymark certificate.

Following safety factors were assumed:

- Safety factor taking into account the pipe heat losses in the collector field and transmission lines f_P=0,96.
- Safety factor taking into account measurement uncertainty f_U=0,95.
- Safety factor for other things. (non-ideal flow distribution and unforeseen heat losses) f_O=0,95.

The target value was exceeded by 6%.

On April 14th 2016, in a clean sunny day, a peak radiation of 1143 W/m2 was measured by the secondary standard kypp & zonen pyranometer. The correspondent peak solar heat output reached 702 kW.

5. YEARLY AND MONTHLY DATA

5.1 Solar irradiation

In the design phase it has been assumed an annual value of solar irradiation on the collectors (tilt 35°, azimuth 2°) of 1439 kWh /m^2

The actual radiation was measured by a Kypp & Zonen, secondary standard pyranometer. (secondary standard is the highest available precision class). During the considered period the measured solar irradiation has been 1361 kWh/m2, that is 5% less than expected.

December and January are the months with the greatest percentage negative deviation.

This fact is due to the substantial shadowing from high trees locatednear the east and south borders of the area. The shadow affects the solar field mainly during the winter season.

Fig. 3 – December 15th 2016, h13.30: shadow covers approximately 2/3 of the solar field.

Both positive and negative differences detected in other months are in percentage smaller and reflect usual variations of the meteo.

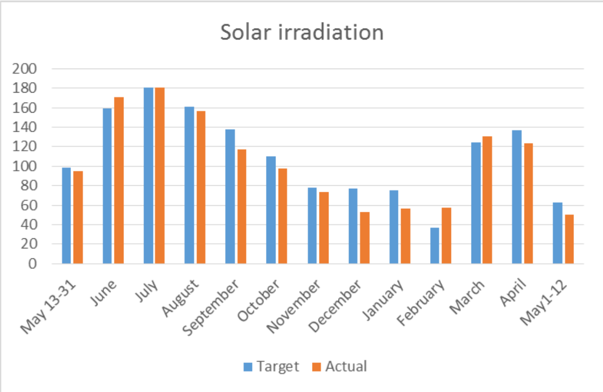


Fig.4 – Solar irradiation month by month

5.2 Return temperature

We define return temperature as the temperature measured at the return pipe on the secondary side of the solar heat exchanger, that is identified as TT7101 in fig.5.

The design value of the return temperature at the solar heat exchanger has been assumed constant all over the year and equal to 65°C, the same as the nominal value of the return temperature of the district heating network.

Actually, the return temperature from the district heating network has been not constant, and sometimes it exceeded 70°C.

As described in chapter 2, the flow coming from the return line of the district heating, is cooled by the replenishment water, before entering the solar heat exchanger (see fig. 2).

The cooling effect is considerable in the morning and in colder season.

For calculation of average monthly return temperature the values measured at 1’ intervals were taken, keeping only values detected in presence of positive flow.

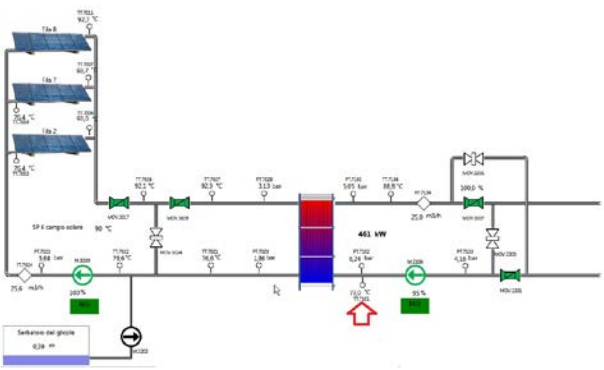


Fig. 5 – Scheme of heat exchange unit. The arrow shows the return temperature measurement point.

Only in 2 months the average return temperature is higher than the design value. During all other months, the average return temperature is lower. The maximum difference (30°C) is in December, that is the month with the least solar irradiation and the least energy output.

Questo indica l’efficacia del sistema di preriscaldo dell’acqua di reintegro.

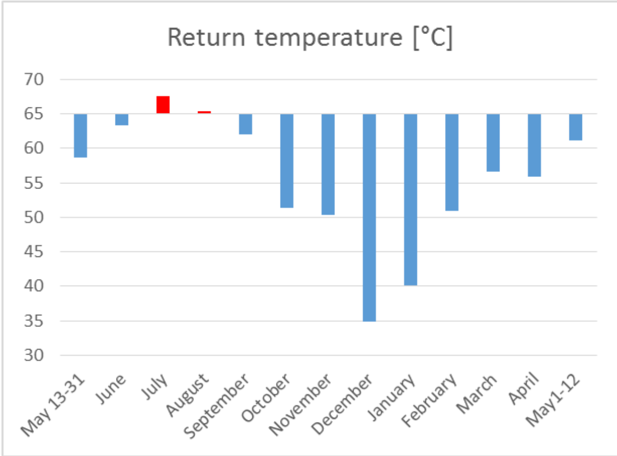


Fig.6 – Deviation from design value of return temperature.

5.3 Solar thermal energy output

The target solar energy output of 450.523 kWh/year, (that is 489,70 kWh/m2 related to the aperture area) has been estimated by mean of a T*Sol simulation.

The simulation was taking in to account no shadows at all.

The actual output obtained during the first 365 days of operation of the plant is 504.400 kWh, that is 11,96% higher than the target value.

The result is remarkable, when you consider the presence of shadows and the lower than expected irradiation, as described in par. 5.1.

Such achievement is partially to be attributed to the reduction in the average return temperature obtained by the make-up water preheating system. However, the performance is in any case higher than explainable only by this fact.

For example, looking at the data of July, you can notice that, despite having an average return temperature higher than the design value, and having had a quantity of solar radiation in line with the foreseen value, the energy output is nearly 19% higher than expected!

In August, the average return temperature has been nearly in line with expected value (less than 1°C higher) and the solar irradiation has been 3% less. The useful energy yield exceeded the target by 14%.

On the other hand, during winter season, the performance has been lower than expectations, despite of a very low return temperature. But it is clear that a shadowed solar field cannot produce energy, whatever low the return temperature.

In general, when detected solar irradiation is higher than the foreseen, the output is even more than proportionally higher. When solar irradiation is lower than expected, the output is sometimes lower than the target, but less than proportionally.

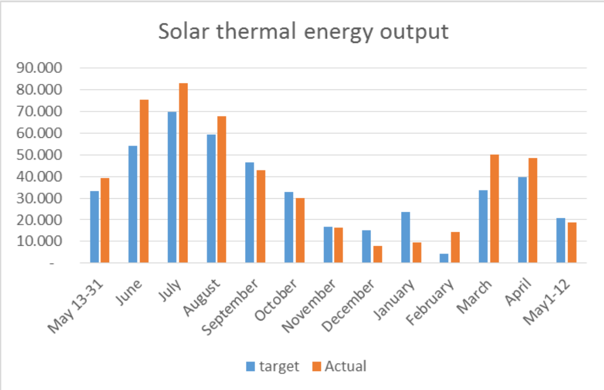


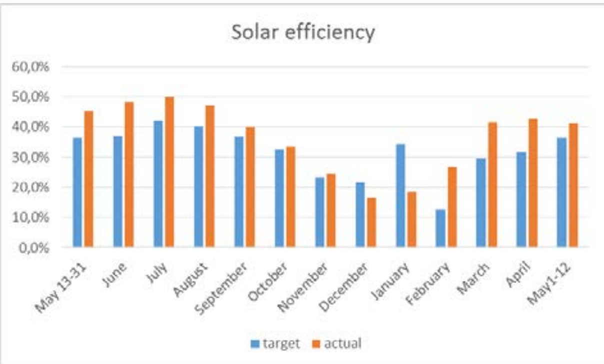
Fig. 7 – Monthly values of solar thermal energy output

5.4 Solar efficiency

Solar Efficiency, defined as the ratio between solar thermal output and the irradiation on the aperture area of solar field, confirms what stated in previous paragraph.

Solar efficiency is, in every month of the first year of operation, higher that foreseen, with exceptions only of December and January when the shadowing is relevant.

The yearly efficiency is 40,27%, that is more than 6 percentage points higher than the target.



6. O&M COSTS

6.1 Maintenance

Besides the routine inspections of the solar field and related equipment, that have been included in the daily operations of the district heating plant, the only maintenance activities were related to the episode of stagnation mentioned in section 3.

A stagnation episode as happened on August 17 2015, that implied the collector temperature rise up to 200 °C has to be considered as exceptional in this plant, that can occour only in case of a serious failure.

During normal operation, the size of the heat storage tanks, together with the heat losses of the heat distribution grid are more than enough to take all the energy produced by the solar plant, even in the sunniest summer days.

As a result of stagnation, the following activities were necessary:

1. Manual re-start of the solar plant
2. Visual check of hydraulic connections, particularly where more thermally stressed by stagnation.
3. Replenishment in the solar circuit of the liquid lost because of evaporation (the solar fluid is a propylene glycole and water misture, but only the solar fraction needed to be integrated).

6.2 Operation costs

The main operation cost is due to the power comsumption of primary and secondary pumps.

Primary pump (solar circuit) consumed 2254 kWh_{el} during the first year. The secondary pump 1080 kWh_{el}.

The total consumption of electric energy by the pumps is 3334 kWh_{el} that in relation to the output results 6,59 kWh_{el}/MWh_{th}. Given a cost of 0,17 €/kWhel, the operation cost of the solar thermal MWh is 1,12 €.

This is higher than usual values of Danish solar district heating. The reason is the fact that return temperature (although reduced by mean of the pre-heating of replenishment water) is anyway higher than Danish plants. A higher return temperature imply a reduced deltaT in the solar circuit, and so higher flow rate per square meter.

7. CONCLUSIONS

The encouraging overall achievements in terms of performance are a fact, and the relavant overcoming of targets cannot be fully explained just by mean of data aggregated on monthly basis, as done in this paper.

Certain is that so good results became possible thanks to a high overall quality of the design, of the components and of the installation of the plant.

The yearly solar yeld, when related to the aperture varea of the plant, amounts 548 kWh/m2, that is among the highest values obtained in similar cases in Europe.

We can therefore say that it is well demonstrated the technical feasibility of the solar district heating, in combination with the typical medium-high temperature networks of the Italian context.

The lack of a forward-looking national energy policy is probably the only real obstacle for the realization of other solar district heating plants in Italy.