Floating thermal collectors on top of seasonal water pit storages

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2018

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The solar irradiation hitting the top of the water pit storages is sufficient to heat up the water volume if it is harvested. The concept develop integration between solar thermal collectors with the floating heat insulation in a system, that will allow to harvest the solar irradiation and at the same time to keep it for seasonal usage. As result of the proposed system the usage of land for solar fields aside of the seasonal storages will be avoided and the total cost of the SDH will be diminished. The system is solving problems like wind, evacuationg of rain water, melting the snow, and other maintanance issues. In addition the system can be applied in existing water volumes, near by urban areas, where water volume is used without need of any building process and laining. It is evaluated optimal depth of the seasonal water pit as function of the harvested energy and the expected losses. It is evaluated expected minimization of the total installation cost, comparing with installation where solar field is placed in a land aside of the seasonal storage.

1. INTRODUCTION

Ground mounted collector areas for district heating are seen in e.g. Sweden, Denmark, Austria and Holland. They are oriented towards south and the distance between the solar collector rows and the angle from horizontal is optimised for each place and collector type. Normally for 1 m2 solar collector 3-4 m2 land is needed. The distance between the solar collector rows is normally at least 4.5 m (depending on the collector height) – measuring from the front of a collector row to the front of the next row – allowing people to move around between the rows. Larger distances give higher production because of less shadowing but also higher costs for ground and piping. [1].
The seasonal storages are crutial solutions for achieving bigger solar energy fraction in the DH mix. In order to use the full capacity of the solar field, assuming very little consumtion of DHW in the summer months, approx 65% of the harvested energy needs to be stored for seasonal use. Converted in water storage volume it is evaluated, that each 1m2 collector aperture needs 11m3 water volume (Table 1).
Pit thermal energy storages (PTES) are constructed without static constructions, by means of mounting insulation and a liner in a pit. The design of the lid depends on the storage medium and geometry, whereas in the case of gravel- or soil / sand-water thermal energy storages the lid may be constructed identical to the walls. The construction of a lid of a water PTES requires major effort and is the most expensive part of the thermal energy storage. Typically it is not supported by a construction underneath but floats on top of the water. By definition, pit thermal energy storages are entirely buried. In large PTES the soil dug from the ground is used to create banks which make the storage somewhat higher than the ground level. The lid can be only equipped with a membrane for rain and UV protection. [2]. Typical section is shown in Fig. 1.

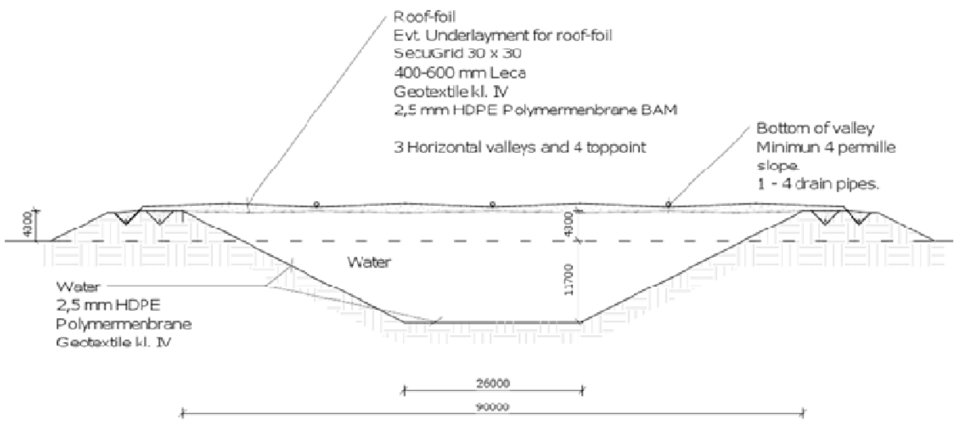

Fig. 1: Construction cross section of the 75,000 m³ PTES in Marstal. (Source: PlanEnergi)

solar radiation at 1m2 aperture area in Varna, Bulgaria						
	0 degree			35 degree		
Month	Hm	COP	harvested	Hm	COP	
1	44	53%	23	71	53%	37
2	61	67%	41	88	67%	59
3	108	78%	84	133	78%	104
4	144	81%	117	157	81%	128
5	191	83%	159	188	83%	157
6	206	85%	175	191	85%	163
7	214	86%	184	204	86%	176
8	193	86%	166	205	86%	176
9	132	83%	110	161	83%	134
10	87	79%	69	122	79%	96
11	52	67%	35	82	67%	55
12	38	50%	19	62	50%	31
Yearly	1470		1182	1664		1314
summer	to be stored		795			805
winter	direct use		387			509
% storage of total			67%			61%
storage volume m2			11			11
after 20% losses and heat capacity 60kWh/m3						

Table 1. Solar radiation at 1m2 aperture area of collectors at 0 and 35 degree inclination and needed storage volume for 100% heating use in Kinder garden (excl. DHW consumption), Varna, Bulgaria

2. PROBLEM DEFINITION

The successful integration of SDH in the urban areas is facing the problem of the land use and related costs and general lack of free space. Land areas are needed for both – collector fields and storage. PTES has proven to be one of the most feasable storage sollutions, however, not including investment for land use, which can be significant in urbanised areas. Furthermore, pit storages include sophisticated and expensive cover lid with low static bearing capabilities. The area of this cover lid is significant compared to other storage types and implies high land costs. In addition, long distances from the solar field to the DH network are causing additional losses and infracstructure investments. In this sense, it is very logical to look for technical opportunities to use this area for solar collector field.

The main technical challenges to locate solar collectors on the top of the floating lid are:

- Low bearing capacity of the lid cover
- Evacuation of rainwater
- Mechanical wind resistance of the collectors
- Penetration and lid tightness issues
- Difficult maintanance of the floating lid cover

Those problems are the reason why up to date no SDH with floating sollar fields has been built. It is necessary not just to adopt and adjust existing storage and collector sollutions, but create an entirely new system, as a result of integrated design, able to overcome the challenges listed above.

3. CONCEPT

The proposed system solves integration between solar thermal collectors with the floating heat insulation on top of the seasonal water storages. It will allow to harvest solar irradiation and at the same time to keep it for furher use. It is fully prefabricated, modular and easy to install on top of the water volume (Fig3.)

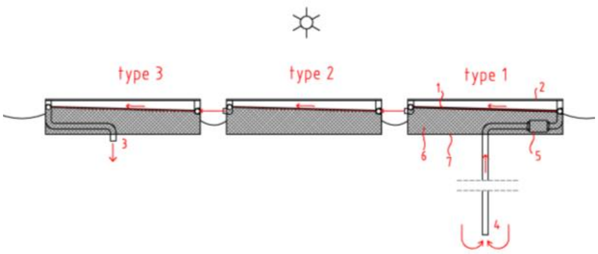

Fig. 3 Floating collectors principle:
The absorption surface (1) is mounted below horizontal glass top (2), covering the floating heat insulation plate (6). There are 3 types of collectors: Type 1 – including input hose (4) sucking cold water from the bottom of the storage volume through the pump (5), Type 2 – transfering collector, Type 3 – including output hose, that injects hot water on the top layer of the storage volume. There are strings formed after connection of the three collector types (with multiple type 2 collectors on each string, depending on design requirements). The collectors are connected with fast plug in connections (both - pipes and bodies), forming solid floating platform. The bottom of the insulation plate is covered with high temperature water resistent linen (7), preventing the insulation from getting soaked with water.

4. DETAILED SOLUTION

The proposed modular collector field is floating over the PTES, integral part of its design and is assuring for both: harvesting and storing the solar energy. It injects the thermal energy directly into the top level of the storage with no additional thermal losses.
As being modular and rigid – the system is assembling very fast, by clicking together plug in connections. In addition a silicone strip is closing the gaps between the panels. Vacuum drainage system is integrated. Such system does not need any slopes of the roof surface in order to evacuate the rain water out of the storage surface. Details are shown on Fig. 4.

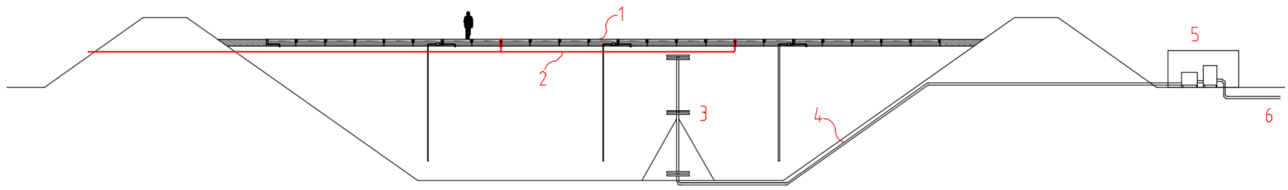

Fig. 4 Principle of floating collectors on top of the hot water pit storage
The floating collectors (1) are forming solid floating platform on top of the hot water pit storage. The vacuum drainage system is evacuating the rain water outside of the storage volume (2). The collectors are sucking cold water from the bottom of the volume, transferring it from the collector's aperture surface, and when heated – injecting it on the top of the volume. All the pumps of the Type 1 collectors are working with variable flow and managed from automation system. The thermal energy is distributed from the distribution column (3) through the pipelines (4) to the power station (5), where the heat exchangers, circulation pumps and water treatment system are installed. If needed – the output energy can be preheated. From the power station the energy is transferred to the DH network (6).

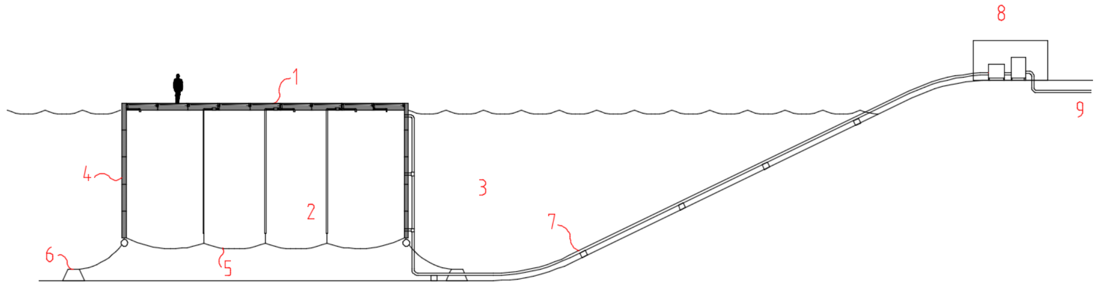

Fig. 5 Principle of the Floating cell
The floating collectors (1) are forming solid floating platform on top of the existing water basin (3). Surrounding heat insulation panels (4) are separating the hot and treated water (2) from the water of the basin. The bottom membrane (5) is closing the volume of the treated water. There is no need for heat insulation at the bottom: the heat is stratified in a normal way in the upper part of the volume, reaching the bottom temperature similar to the exterior basin temperature. Distribution tubes (7) laid on the basin bed are transporting the thermal energy from the floating cell to the power station (8), where the heat exchangers, circulation pumps and water treatment system are installed. If needed – the output energy can be preheated. From the power station the energy is transferred to the DH network (9).

Moreover, the proposed system can work as independent solar heat collector and storage cell, mounted inside an existing water volumes (lakes or seashore bays). The proposed system may achieve radically low investment cost compared to existing PTES. Principle scheme is shown on Fig. 5

5. BUSINESS OPPORTUNITIES

The total cost of SDH is a function of installed collector field, price of the land and cost of the seasonal storage:

T (total cost euro/m2 apreture area) = C (cost of installed collectors) + L (price of the land) + St (storage cost)

According to IZEB studies on the SDH market [3] the cost of the collectors depends on the origin, qaulity and warranty given. The cost of the land is significant factor, that may impact on the SDH commercial viability when applied in urban areas. The construction cost of PTES is already confirmed by many successful projects to be the most cost efficient solution at the moment. [4]

With the proposed system there are savings in the following aspects:

- Land for the collectors field
- Heat insulation on the back of the collectors
- Auxiliary mechanical support for the collectors
- Storage basin excavation (in case of floating cells in existing basins)

In addition some negative sides of the state of the art PTES are overcome:

- The sophisticated cover installation, and the filling up process is becoming easier: just filling up the volume and installing the moduls with fast plug in connection.

- Rain water evacuation with pupming from the center is replaced with standard vacuum drainage system, where no slopes are needed, and where evacuation tubes are mounded below the floating collectors.
- The system consists of small size panels, easy for production and instalation with low installation costs

6. CONCLUSIONS

The floating collectors on the top of PTES represent an integral solution overcoming most of the technical and financial challenges for locating collector fields over storage facilities. Early calculations estimate a price reduction (incl. Price for land use) between 15 and 20% compared to conventional SDH technologies. This solution allows achievement of SDH facilities with close to 100% solar fraction and reduces significantly energy transport losses. It will introduce SDH concept to urbanized areas, increase general social awareness and contribute for better air quality. This promising technology gives new perspectives and opportunities for the SDH sector. Modular, scalable and prefabricated design approach will both reduce prise and increase productivity.

7. CALL TO ACTION

This new integral solutions requires significant R&D effort in order to find industrial implementation. There are still some technical challenges which need to be solved and industrial production requires close cooperation of research and business partners. Institute for Zero Energy Buildings is looking for organizations sharing a vision for low-carbon EU perspectives.

8. REFERENCES

Literature:

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