New Technology produces Economic Solar-Electricity combined with seawater desalination

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Summary:

The increasing demand on electricity forces all governments in the world to build new power stations. The trend goes to co-generation. Using the waste heat either for heating houses or for sea water desalination, this raises the economics of such power stations.

However, the increase of power generation, even with efficient techniques like combined cycle technology and adding heat or desalinated water to the output of the power station increases essentially the emission of carbon dioxide.

Photovoltaic as an alternative cannot cover the demand because of its elevated costs; also wind energy fails to cover the increasing demand as it is economic only in regions with high and constant wind velocity; moreover both do not offer the option of combined – therefore economic - desalination.

A real alternative to fuel firing is the use of solar heat to generate steam. This was till now still more expensive than conventional firing. However, due to a new technology using flat mirrors for concentrating sunrays on a tube, very good results can be achieved reducing electricity generation costs to be competitive with fuel firing and enabling operation either as decentralised stand alone units or for large power stations of the order of 800-1000 MW.

Other advantages like using the area under the flat mirror solar collector for planting and housing as well as combination with cooling and seawater desalination gives this technology a real chance to generate electricity on a large scale and at the same time recreating large desert areas in arid regions.

Global site and situation overview:

Egypt lies in the middle of the so called “sun belt” extending from west Morocco over North Africa, Arabian Peninsula, Iran and Pakistan. At the south-west corner of Egypt, Oweynat, the hottest spot on earth was defined.

Egypt’s extended coasts of about 2000 km beside the mentioned favourable sun irradiation are ideal conditions for large solar thermal power stations which are simultaneously used for seawater desalination by means of their waste heat.

Seawater desalination is still expensive; however, it is one of the options discussed seriously now to hold control on the expected water deficit expected in 15 to 20 years, which is estimated to be one third to half of Egypt’s consumption now.

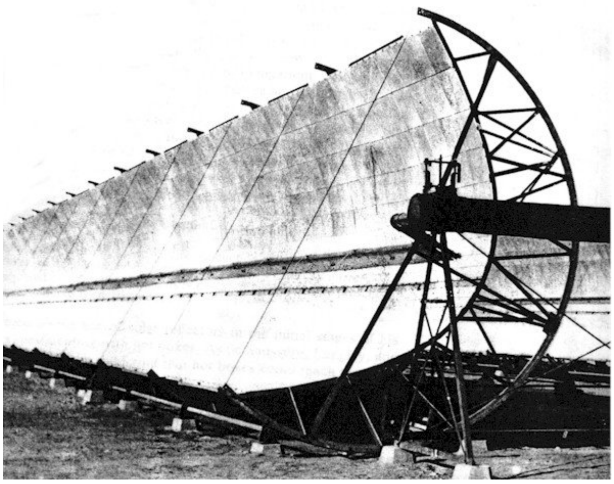
Once sufficient electricity is produced, export of the same to Europe becomes an option. High voltage lines are already connecting the southern Mediterranean with Europe and are used to transfer electricity between Libya, Egypt, Jordan and Syria pending signing contracts with Turkey and the European Union.

Historical and technical overview:

The first solar thermal facility to produce electricity was installed 1912 by an American called Shuman in Maady, Egypt. The technology applied was the parabolic mirror trough, consisting of a longitudinal parabolic formed mirror concentrating sunrays on a line focus in which a tube was situated containing water that was brought to evaporation. It produced 55 kW electric power.

The project was not continued to commercial production of electricity.

See photograph to the right



The solar concentrating technologies applied today may be classified in two categories:

- The point concentrating technologies are the solar tower and the solar dish. They achieve high concentration of the sunrays to reach temperatures over 1000°C.
  The solar dish is limited to small applications up to 50 kW maximum.
  The solar tower using mirrors on the ground called heliostats which are tracking the sun to throw the rays on the collector placed at the top of a tower can reach values of 50 MW
- The line concentrating technologies are the parabolic trough and the Fresnel technology. The parabolic trough is successfully used in the Mojave desert in California to produce 354 MW electric power with several modules of 30 to 80 MW each. It consists of several rows of two dimensional parabolic mirrors concentrating the sunrays in their focus in which a vacuum jacketed tube is placed. In the tube synthetic oil flows which is heated to about 400°C. Each row including tube is movable to track the sun. Free areas between the rows, about 2:1 are foreseen to prevent shadowing each row on the next.
  The Fresnel technology uses flat mirrors as a fragmentation of the parabolic mirror to concentrate on a fixed tube at the top. The flat mirror rows are driven to track the sun.

Description of the technology:

A solar field consists of several lines each 1000 m long and 24 m wide. The orientation of the lines is preferably North-South. The flat mirror segments are mounted on a steel frame at a height of 4 m from the ground and are driven - each row at a different angle - to permanently reflect the sun rays to the stationary collector pipe situated above the mirrors, which is specially coated to allow radiation to enter and prevent heat transfer to the outside. The collector pipe is mounted under a secondary reflector, which collects the sunrays passing nearby the pipe to redirect them to the pipe (see figure below). Further, it protects the absorber pipe against heat losses by air convection. This secondary reflector enables use of the pipe without expensive vacuum jacket.

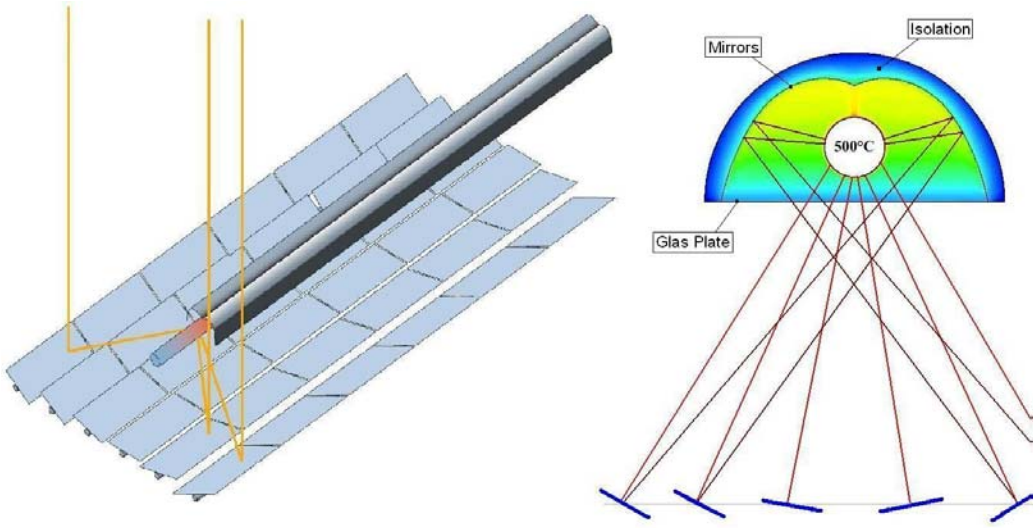
Water pumped in the pipe evaporates to steam with up to 100 bar and 400°C. The steam is then used to drive a conventional steam turbine.

During the night, when the solar field is not used, the mirrors are turned up-side-down and a rotating brush is automatically driven below the mirrors to clean them from the dust which felt during the day. This automated periodic cleaning may be done every night or less frequently depending on the concentration of dust in the air.

The simple construction with flat mirrors and light weight steel structure – both available in Egypt – as well as small motors for mirror drive using thin cables, enables a considerable cost reduction.

The fact that it covers completely - without negligible spacers - the area available, makes it most efficient in collecting nearly all falling sunrays resulting in a high production of electric power per area available.

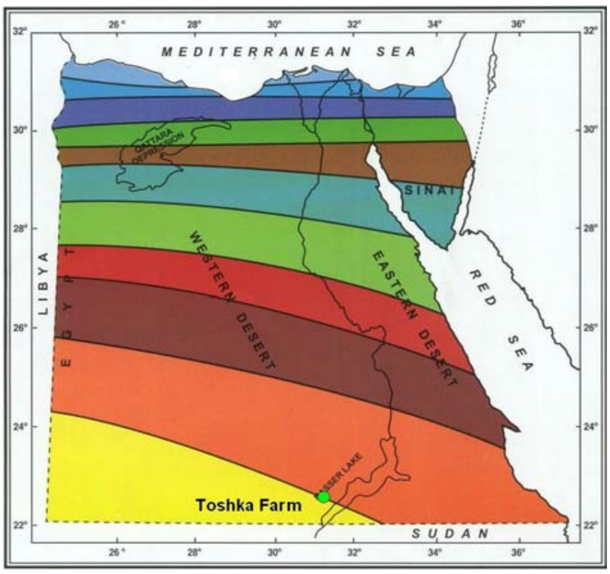
The area under the collector is usable for planting, parking cars or developing flat buildings to reduce direct sun radiation and improve air conditioning performance in summer.



Source: Solar Paces 2002, Andreas Haeberle,
Calculations of heat losses at 500°C estimated steam temperature

<u>Case study:</u>

The following describes a project proposed by the author for the social and economic development of an experimental pioneer farm in the region of Toshka.



Position of the farm

Start of construction

Constructing the canal

Lining the canal

The farm has an area of 1000 Feddans (approx. 4 200 000 m²) situated about 130 km west of the Nile valley, approximately on the 23° latitude. Due to this situation, lines to connect the farm to the grid are extremely expensive. Also transportation and storage of fuel for power generation by means of a diesel generator unit may cause unexpected costs.

For these reasons a decentralised, stand alone, energy production from the sun was suggested. This is favoured due to the fact that the farm area is on the boundary of one of the hottest spots on earth with more than 360 days per year of cloudless sky ensuring continuous electricity production at higher efficiency than elsewhere.

The high sun irradiation causes extremely harsh conditions for agriculture and living for humans and animals. Water for this and further farms will be brought from the Nile by means of the "Sheikh Zayed Canal" now in construction, however, the development of a community in this desert region needs additional incentives, which are necessarily linked to higher electricity demand combined with high demand on potable water for personal use and food processing industry.

The new approach to concentrating solar power using flat mirror concentrators is excellently suitable for the general development of that sunny and hot area far from infrastructure because of its multiple synergy effects that offer solutions to planting delicate plants in the shadow, living and working in air conditioned rooms, sufficient power during day for irrigation pumps and food processing industries including chilling and freezing, also sufficient power during the night for normal social activities. It offers also a cheep possibility for desalinating brackish water and salty water from wells.

From author suggested decentralised power generation for a Farm in southern Egypt. 80 m² reflector area arranged in 4 rows to produce electricity, desalinated water and cooling for farm inhabitants, animals and food processing industry. Source of graph: FHG-ISE.

This system is affordable for the following reasons:

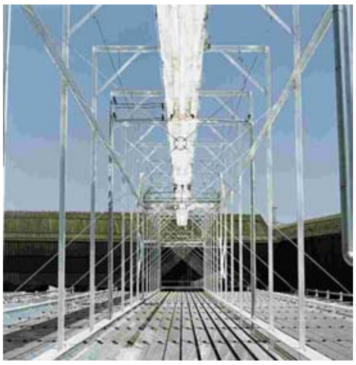
- The simple construction allows its erection without strong foundations, with about half the costs of other solar collectors and to a very large extent with the help of local man power. Moreover
- About 50-60% of the material is produced in Egypt, like flat mirrors, light steel sections, cables and motors for the mirror drive.
- Maintenance of the collector does not require highly qualified personnel. The main item of maintenance is the periodic cleaning of the mirrors. This was automated thus reducing costs and risks that the mirrors break.

The Sun radiation is used for Power Generation:

A solar collector of about 80 000 m² allows for high grade steam generation delivering up to 45 MW(thermal) peak power. That thermal power can be used for multiple purposes:

  - to drive a small steam turbine generating electric power (about 7 MW). This power could be used by the local farming industry (for irrigation pumps and food processing).
  - to drive an absorber cooling machine. The cooling power could be used for refrigerators - needed for vegetable storage -, freezing part of the farm production for shipping, or for centralised air conditioning systems.
  - to drive multi flash (evaporative) water desalination units for the treatment of salty and brackish water found in the local underground. The potable water produced – needed for humans, animals and food industry - can run up to 800 000 m³/year. The potable water exceeding the needs of the farm may be sold to neighbouring villages, thus increasing the farm's income.
  - to decontaminate the water from the Nile delivered by the canal
  - to charge a thermal heat storage for night operation.

The area under the collector (flat mirror roof located between 3 and 5 meter above the ground) can be used for multiple purposes:


Flat Mirrors concentrating to Tube on top


General view


Shadowed usable area below flat mirror roof

- Agriculture. In the shade the plants will need less water for irrigation (lower evaporation) but get sufficient indirect light to ensure growth. It is an ideal place for agricultural research intended in this experimental farm. The water used to wash the mirrors will drop on the plants. It is also possible to use excess water for cleaning the mirrors and so spare an irrigation device for the plants under the mirror roof.
- Living and working area: Housing and/or manufacturing areas can also be developed under the mirror roof. They will need much less air conditioning as they are protected from direct sun radiation. For the same reason, stables or chicken farms could also be developed under the mirror roof.

The high availability of extraordinary sun radiation in this area and the high degree of collecting the sun rays by the flat mirror technology allows a significant fuel saving of about 7000 t/year compared to generation of the same power by means of a diesel-generator unit. Moreover, all problems involved in transportation and storage of fuel are eliminated.

Processing food on site by the generated electricity and the purified water gives the possibility to cultivate more valuable crops like vegetables and freeze them for transportation to the markets in the cities of Egypt or even to export to Europe and Arab countries.
The rapid growth of the plants in this region gives the advantage that the products can be presented in the markets about one month earlier than their usual season.

The economic and social development of the population in this region will be strongly promoted due to the technology transfer and workmanship needed for erection of the solar field and - once that the plant is running - due to the better living and income conditions offered by the mixed agricultural and industrial structure.

Conclusion:

The case study to supply a farm in Toshka with pure solar power covering its demands and enabling social and economic development of the community proves the applicability of this concept.

The same strategy may be applied on large scale to produce electric current covering Egypt's demands and yielding surplus for export to Europe simultaneously covering a considerable portion of Egypt's future water demand as the following example shows:

A square of 32 by 32 km equals an area of 1024 km² which is 0.1% of Egypt's total area. It is a negligibly small area compared to the vast deserts in North Africa.

Using the flat mirror technology, this area is capable to produce 10% of the consumption of the European Union and at the same time 12 000 millions m³ of desalinated seawater from the waste heat covering almost 20% of Egypt's consumption today.