Mini Solar Thermal Power Plants

A

Flexible
Robust
Efficient
Sustainable

solar thermal cogeneration system

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Introduction

Mini Solar Thermal Power Plants (MSTPPs) are a combination of a concentrating solar collector and a steam motor. MSTPPs directly compete with large scale photovoltaic systems above 100-200 kWp, but differ to them with the following two major advantages:

1. MSTPPs not only produce electricity, but at the same time deliver valuable thermal energy as by-product
2. With the possibility of the integration of a cheap and simple energy storage and in combination with other thermal energy forms MSTPPs are also capable to deliver fully dispatchable load up to base load.

Basic configuration
The Mini Solar Thermal Power Plant (MSTPP) in its basic configuration is a combination of a concentrating Solar Collector and a steam motor generator set with its infrastructure to produce electricity. The solar collector produces saturated steam with a temperature level of about 260℃ that is dir ectly used in a steam motor.

Advanced configurations
In advanced configurations MSTPPs can be complemented by a high temperature heat storage and / or a second heat source and / or various heat usage applications to the basic system.
The heat storage helps to use solar power that exceeds the motor capacity during high radiation periods and will extend the operating time of the system beyond the time of minimal necessary solar irradiation. The integration of a second heat source (e.g. a biomass or biogas boiler) makes it possible to produce base load and to adopt the energy production to the demand.

Heat usage applications can be on

- a high level temperature of up to 260℃ using stea m that comes directly from the solar collector
- a mid level temperature around 95℃, using the exp anded steam that leaves the outlet of the steam motor.
- A low level temperature of about 60℃ leaving the motor cooling system

Function principle

The Fresnel reflectors concentrate the direct solar radiation to an absorber in which water is heated and evaporated at about 260℃. The steam in turn is converted into mechanical energy through a steam motor and then into electricity using a conventional generator.

The exhaust steam from the steam motor can be applied as driving fluid for processes such as absorption cooling or water desalination. Furthermore the low temperature heat from the motor cooling system can be used for purposes such as room or water heating.

The vapour / steam from the collector field that exceeds the motor capacity can

- either be used directly for high temperature applications as for example industrial processes in the food or chemical industry or
- transmit its heat to a storage system that assures that electricity can even be produced when solar radiation alone is not sufficient to run the steam motor.

The same benefit can also be derived by applying a co-firing system such as a biogas or biomass fired steam boiler.

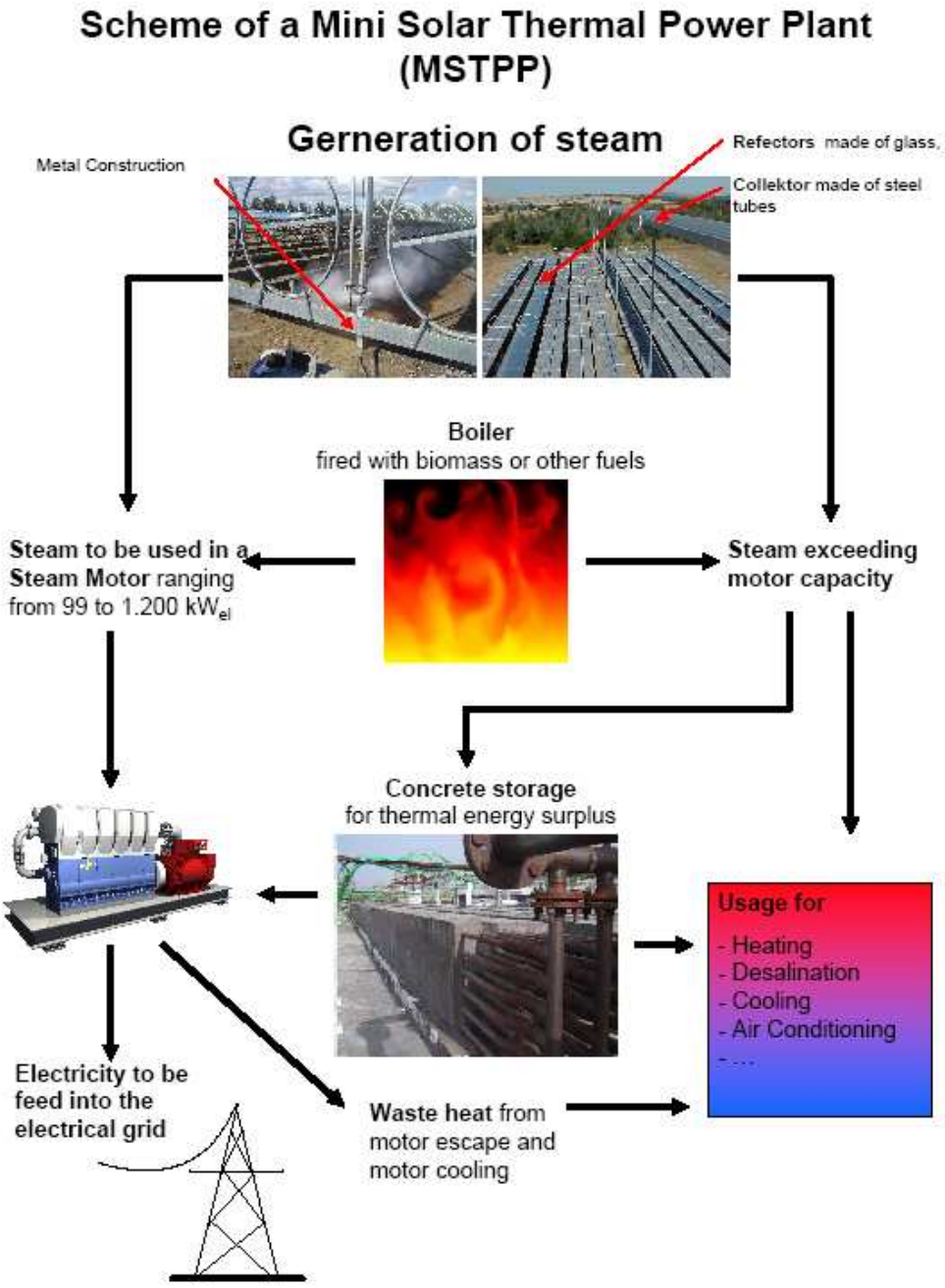

Fig.1: Scheme of a MSTPP system and possible applications

Areas of Application

MSTPPs can be applied for stand alone or combined electricity generation and additional heat supply at different temperature and pressure levels. Thus they offer a smart solution for a wide range of potential application cases. The limits of reasonable applications for MSTPPs are mainly determined by

- the minimal and maximal sizes of available steam motors,
- the available surface area and
- the possible heat applications for the produced steam.

Furthermore the application area of MSTPP is connected with the advantages the system offers in comparison with large scale PV-systems and small scale steam turbine systems.

The minimal size of a MSTPP is determined by the smallest available steam motor size which is about 100kWel. Due to the various advantages of MSTPP systems offer in comparison to photovoltaic systems, we would always recommend a MSTPP system in situations where a high share of direct solar irradiation is available, even more if the waste heat can be utilized.

The upper limit for MSTPP is set by the availability and cost effectiveness of steam turbines appropriate to the characteristics of solar steam generation. The usage of steam motors offers a superior solution up to around 5 MWel in comparison to affordable saturated steam turbines, because of their superior robustness and efficiency at these process parameters.

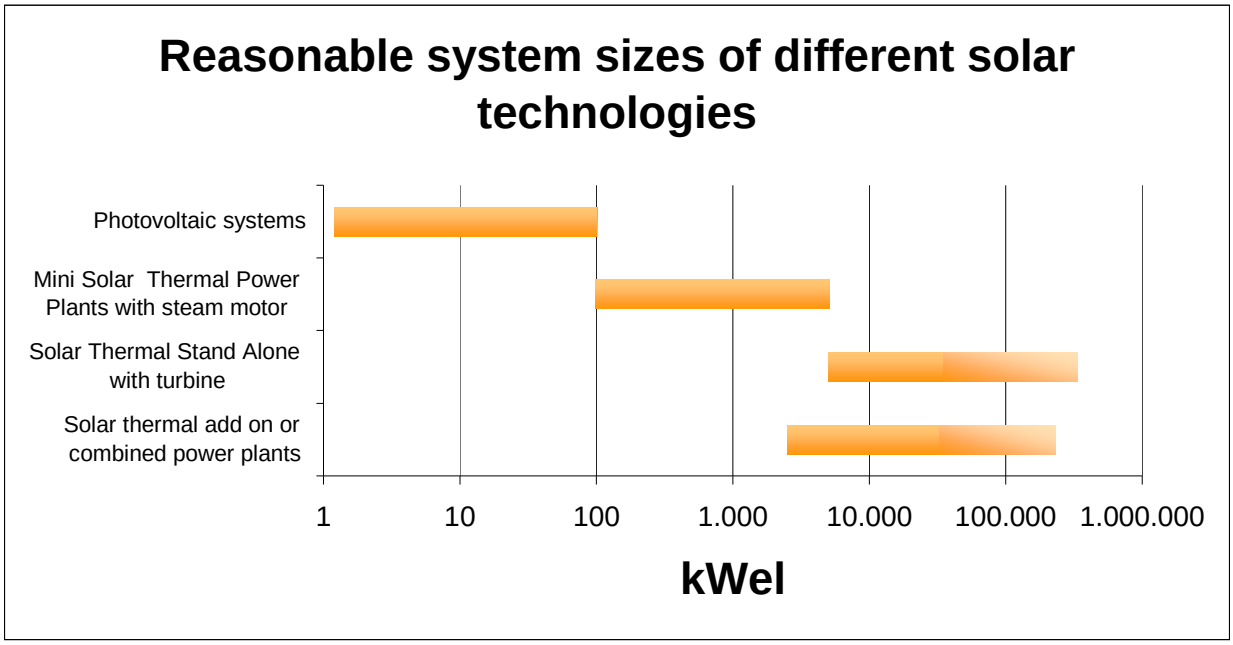

Fig.2: Reasonable sizes for different types of solar systems

Resuming one can say that MSTPP fills an important gap between small local photovoltaic systems that are adequate up to 100kWel and big central solar thermal electricity generation facilities in add on-, combined cycle- or solar thermal stand alone systems. MSTPP are an optimal solution for a flexible, robust, efficient, sustainable, decentralized form of cogeneration at medium sizes.

The Components of the System

Linear Fresnel Collector (LFC)

The Linear Fresnel Collector (LFC) uses flat mirrors which follow the sun to concentrate the sunlight in a spot line. Here the heat is transferred to an absorber in order to produce directly saturated steam.

Different to a system with parabolic collectors the gaps between the mirrors are very small and solar radiation losses due to unused area is minimized. Thus the area below the reflectors is well shaded and can for example be used for car park shading.

The use of standard components aims to reduce not only complexity but also cost of the collector. But the design is smart also in the sense that O&M efforts are limited and danger of destruction during harsh weather conditions is reduced.

Fig.3: Image of a CLFR collector commissioned in Australia by Solar Heat and Power Pty. Ltd.

Consequently the collectors various benefits are:

- Demand for ground surface area for collector field is reduced
- Good economics of collector due to smart design and use of standard components,
- Low operation & maintainance costs
- Possibility to use the shaded area below the reflectors.

Thus already today Linear Fresnel collectors offer the most cost effective approach for the solar production of saturated steam. The Linear Fresnel Collector concept is a tested technology. A 1 MWth array is already in operation in the 2000 MW Liddell Power Station located in Hunter Valley, NSW, Australia. The extension of up to 15 MWth, covering more than 135.000 m² of ground surface is currently in execution.

Steam Motor

The steam motor concept is an advanced version of the classic steam engine. It combines the thermodynamic benefits of the traditional steam engine with the design features of a modern combustion engine. Steam motors are available up to a maximum load of 1.200kWel

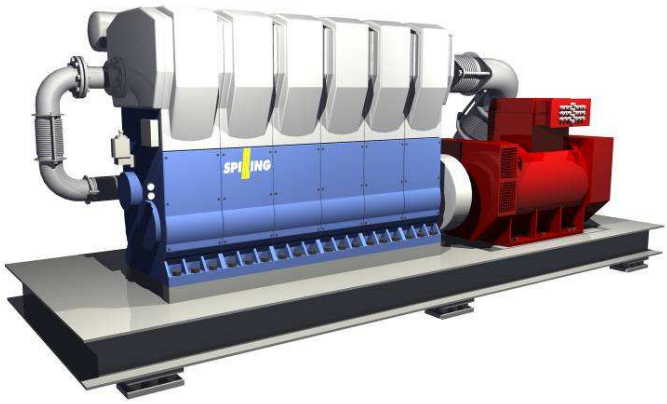

Fig 4. Impression of a Spilling Steam Motor

For small solar thermal electricity generation applications from 100kW$_{el}$ up to 5 MW$_{el}$, the steam motor is the best option. Small steam turbines tend to be rather inefficient and sensible to the moisture content of the incoming steam. Furthermore a normal steam turbine can not work under 40% of its nominal capacity.

In contrast a Spilling motor can work without any problems

- at 25% of its nominal capacity and
- even under fluctuating steam conditions and high moisture steam.

These features provide valuable extra operating time to a solar thermal power plant which most of the time will receive incoming solar radiation at a lower level than the design value (mornings and evenings, and even during lunch-time during winter).

Thermal Storage

A simple solar thermal plant will only be able to run during daytime when the direct solar radiation is high enough to evaporate sufficient steam in the absorber. But other than for PV plants the energy harvested from the sun can relatively easy and cost-effective be stored in the form of heat for example in a simple insulated heat resistant concrete block with steel heat exchanger tubes cast inside.

A system of this kind has successfully been tested in Almeria in the year 2004. The storage is loaded while vapour flows through the tubes inside of the block and transfers its heat to the concrete. The storage is discharged if water is pumped through the tubes inside the heated block. In the tubes the water vaporises while the heat is re transferred from the concrete to the water. So there is a great flexibility in the time of supply of electricity to the grid, as the conversion can be timed in a manner that optimum benefit for the grid is gained.

A storage significantly helps to optimize the relation between investment and income. Without storage, a solar plant in Southern Europe can operate only about 700 hours at full load and about 1100 hours at part load. With a 5-6 hour-storage system, a solar plant in Southern Europe can about double its full load operation, which will have an immediate effect to the economics of such system.

Additional applications

From the thermal energy that is used in a MSTPP results a second big advantage of the MSTPP in comparison with PV systems that only produce electricity: An MSTPP is an ideal instrument to provide electricity, heat, cooling and other benefits at the same time, and at the location of demand. The possibility to use waste or surplus heat opens a variety of new areas for the utilisation of solar energy, be it in industrial and agricultural processes, applications of residential or touristic character or commercial / administrational buildings.
Possible heat applications are for example:

- **Water Desalination** with evaporation systems for new townships, tourist resorts, etc.
- **Air Conditioning** with single stage absorption coolers for shopping centers, hotel complexes, hospitals, etc.
- **Refrigeration** with 2-stage absorption coolers for hospitals, food industry, etc.
- **Process steam** provision for food or chemical industry
- **Hot water** for laundries, kitchens, domestic hot water and room heating for hotels, hospitals, administration buildings, etc.

Hence the site always determines the quantity of heat and the temperature level that is needed for the different types of processes. There is a clear necessity that for every case it has to be analysed individually which options are best. Especially sites with rising demands for cold water, process heat or potable water are very interesting for the application of a MSTPP. Best if the MSTPP can be integrated into cogeneration facilities on the base of biomass or biogas.

But due to its geometry also offers the opportunity to shade places such as a parking lots, plant areas or others that need protection against direct solar radiation. The design of the collector with only small gaps between the mirrors guarantees that most of the area below the reflectors is shaded throughout the whole day.

Advantages

On sites with a high share of direct solar irradiation MSTPP offer various advantages and possibilities compared to big photovoltaic systems of more than 100kWp :

- The production of electricity is cheaper than with PV Systems
- The produced heat offers various and vast possibilities which have the potential to reduce electricity costs even more due to sale of by-products
- The combination with a thermal storage further raises the potential to improve the economic performance and the flexibility of the system
- The possibility of the combination with other boilers e.g. a biomass co- or backup firing offers greater operational flexibility and dispatchability
- The possibility of producing main components of the collector near the site supports the local economy
- Local energy production minimizes the transport losses

All these points lead us to the conclusion that the MSTPP should be preferred in comparison to photovoltaic plants wherever system sizes of 100kWel and larger are required. And this even more wherever there is a coincidence of additional cooling, heating or desalination demand.

Our Service

The site determines the quantity of electricity and useable waste heat that is required, and well as the needed temperature level for the waste heat. The geographic and climatic location determines the potential amount of electricity and heat that can be produced by the system over the year. Hence it is necessary to analyse each site individually.

Therefore we offer various services around the design of a MSTPP. Assisted by a network of regional and international cooperation partners, Solar Heat & Power Europe GmbH has the technical know how and resources to execute:

- Site assessment and project development services
- Feasibility studies and analysis of the generation potential, the needed technical concept and the economic outcome of a MSTPP
- Turnkey supply of the Mini Solar Thermal Power Plant MSTPP

If we have raised your interest we would be delighted to offer our services to you. We will enable you to realize your ideas around the utilisation of solar thermal electricity generation.

Example

The following example was presented during the World Renewable Energy Congress in Aberdeen in May 2005. It is a rough estimate for a simple plant installed in Southern Spain.

• Installed capacity	1,200 kWel
• Investment Volume	4.6 Mio. €
• Annual Electricity generated	1,600 MWhel
• Operating Cost	90,000 €/a
• Land Area Demand	33,000 m²
• LEC (no subsidies considered)	30 c/kWhel
• Useable By-product heat could be used to produce e.g. or 200,000 m³/a potable water	>10,000 MWhth

Since every location will be different, we highly recommend you to approach us for an individual investigation of your case. On your request it will be a pleasure for us to send you a check list to examine if the conditions of the site are promising to further develop a MSTPP project there.

Please do not hesitate to contact us for further information.

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