بسم الله الرحمن الرحيم

Benha University

Dr : Mohamed Ahmed Ebrahim

Benha University
Faculty of Engineering at Shoubra
Electrical Engineering Dept.

Postgraduate (Pre-master) Course

Generation of Electrical Power from Renewable Resources

Dr./ Mohamed Ahmed Ebrahim

E-mail: mohamedahmed_en@yahoo.com

Web site: http://bu.edu.eg/staff/mohamedmohamed033

Syllabus

1. INTRODUCTION.
2. SOLAR PHOTOVOLTAIC POWER SYSTEM.
3. SOLAR THERMAL POWER SYSTEM.
4. WIND POWER SYSTEM.
5. ENERGY STORAGE SYSTEMS.
6. STAND-ALONE SYSTEM.
7. GRID-CONNECTED SYSTEM.

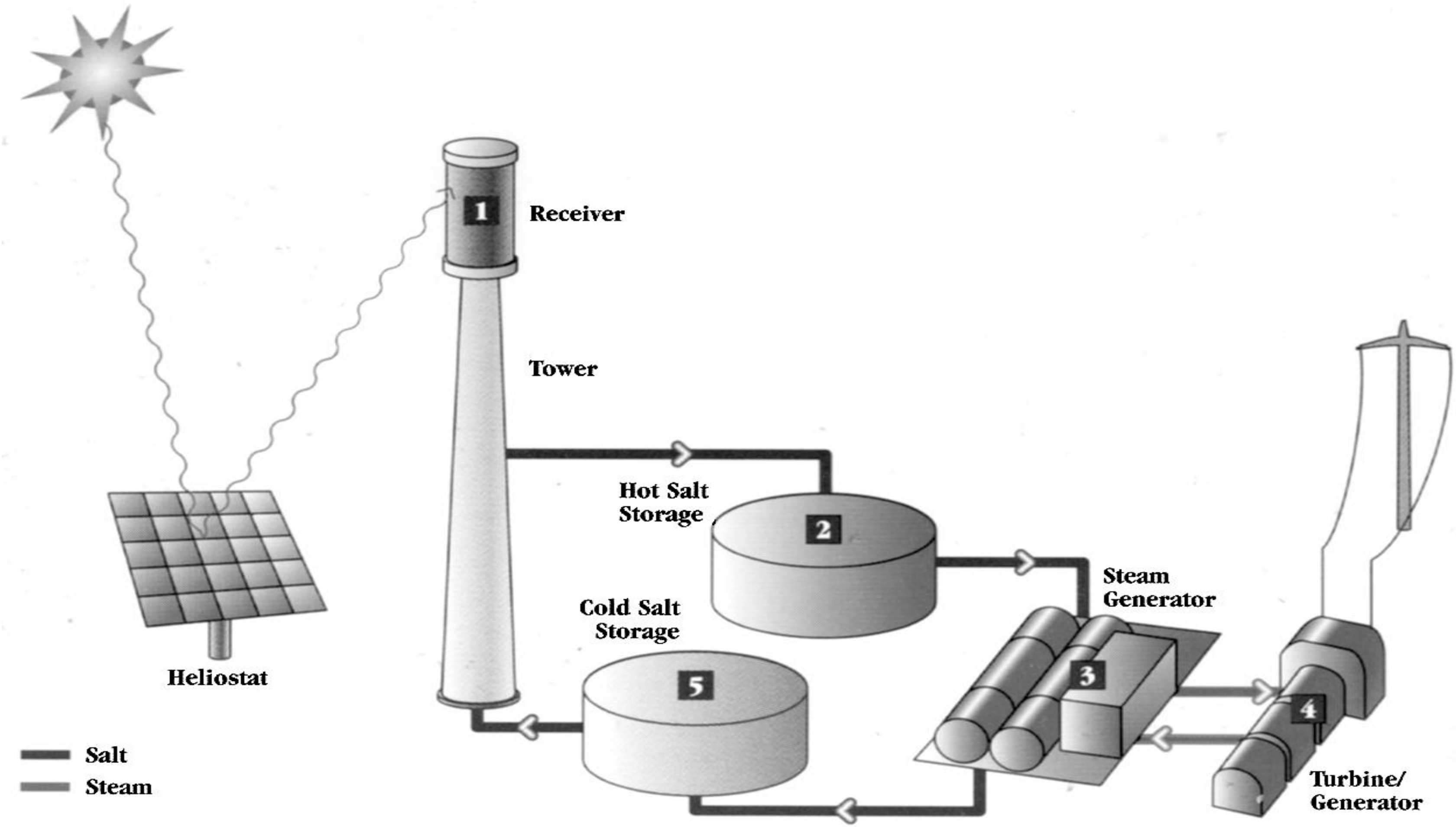
Solar Tower systems

- In this plant, the solar energy is collected by thousands of sun-tracking mirrors, called heliostats, that reflect the sun's energy to a single receiver atop a centrally located tower.
- The enormous amount of energy focused on the receiver is used to generate high temperature to melt a salt.
- The hot molten salt is stored in a storage tank, and is used, when needed, to generate steam and drive the turbine generator.

Solar Tower systems

- After generating the steam, the used molten salt at low temperature is returned to the cold salt storage tank. From here it is pumped to the receiver tower to get heated again for the next thermal cycle.
- The usable energy extracted during such a thermal cycle depends on the working temperatures.

Solar Tower systems



Solar thermal power plant schematic for generating electricity

Solar Tower systems

- The most important feature of the Solar Tower design is its innovative energy collection and the storage system.
- It uses a salt that has excellent heat retention and heat transfer properties.
- The heated salt can be used immediately to generate steam and electric power. Or, it can be stored for use during cloudy periods or after the sun goes down to meet the evening load demand on the utility grid.

Solar Tower systems

The salt selected for this purpose is sodium and potassium nitrate which works as a single phase liquid, and is colorless and odorless. In addition to having the needed thermal properties up to the operating temperature, it is inexpensive and safe.

Solar Tower systems

- Because of this unique energy storage feature, the power generation is decoupled from the energy collection.
- For electrical utility, this storage capability is crucial in that the energy is collected when available, and is used to generate high-value electricity when it is most needed.

Solar Tower systems

- A major benefit of this scheme is that it incorporates the thermal energy storage for duration in hours with no degradation in performance, or longer with some degradation.
- This feature makes the technology capable of producing high-value electricity for meeting peak demands.
- Moreover, compared to the solar photovoltaic, the solar thermal system is economical, as it eliminates the costly semiconductor cells.

Practical Case Study

- An experimental 10 MW_e power plant using this technology has been built and commissioned in 1996 by the Department of Energy in partnership with the Solar II Consortium of private investors led by the Southern California Edison, the second largest electrical utility company in the U.S.A.
- It is connected to the grid, and has enough capacity to power 10,000 homes.
- The plant is designed to operate commercially for 25 to 30 years.

Practical Case Study

Dr : Mohamed Ahmed Ebrahim

technical design features of the Solar II power plant

- The operating experience to date indicates the overall plant capacity factor of 20 percent, and the overall thermal to electrical conversion efficiency of 16 percent. It is estimated that 23 percent overall efficiency can be achieved in a commercial plant design using this technology.

Design features of the Solar II power plant

Site

- Mojave Desert in California
- 1,949 feet above sea level
- 7.5 kWh/m^2-day annual average daily insolation
- 95 acres of land

Tower

- Reused from Solar I plant
- 277 feet to top of the receiver
- 211 feet to top of BCS deck

Heliostats

- 1,818 Solar I heliostats, 39.1 m^2, 91 percent reflectivity
- 108 new Lug heliostats, 95.1 m^2, 93 percent reflectivity
- 81,000 m^2 total reflective surface
- Can operate in winds up to 35 mph

Receiver

- New for Solar II plant
- Supplier Rockwell
- 42.2 MW thermal power rating
- Average flux 429 suns (429 kW/m^2)
- Peak flux 800 suns
- 24 panels, 32 tubes per panel
- 20 feet tall and 16.6 feet diameter
- 0.8125 inch tube OD
- 0.049 inch tube wall thickness
- Tubes 316H stainless steel

Thermal Storage System

- Supplier Pitt Des Moines
- Two new 231,000 gallon storage tanks, 38 ft ID
- Cold tank carbon steel, 25.8 ft high, 9 inch insulation
- Hot tank 304 stainless steel, 27.5 ft high, 18 inches insulation
- 3 hours of storage at rated turbine output

Nitrate salt — Chilean Nitrate

- 60% $NaNO_3$, 40% KNO_3
- Melting temperature 430°F
- Decomposing temperature 1,100°F
- Energy storage density two thirds of water
- Density two times that of water
- Salt inventory 3.3 million pounds

Steam Generator

- Supplier ABB Lummus
- New salt-in-shell superheater
- New slat-in-tube kettle boiler
- New salt-in-shell preheater

Turbine-Generator

- Supplier General Electric Company
- Refurbished from Solar I plant
- 10 MWe net
- 12 MWe gross

(Source: U.S. Department of Energy and Southern California Edison Company.[2])

Operating features of the Solar II power plant

Thermodynamic Cycle	Electrical Power Generator
Hot salt temperature 1,050°F	Capacity 10 MWe
Cold salt temperature 550°F	Capacity factor 20%
Steam temperature 1,000°F	Overall solar-electric efficiency 16%
Steam pressure 1,450 psi	Cost of conversion from Solar I $40 M
Receiver salt flow rate 800,000 lbs/hour	
Steam generator flow rate 660,000 lbs/hour	

(Source: U.S. Department of Energy and Southern California Edison Company.)

Commercial Solar Tower Power Plants

- Based on the Solar II power plant operating experience, the design studies made by the National Renewable Energy Laboratory for the U.S. Department of Energy have estimated the performance parameters that are achievable for a 100 MW_e commercial plant.

Comparison of 10 Mw_e Solar II and 100 Mw_e Prototype Design

Performance Parameter	Solar II Plant 10 MWe	Commercial Plant 100 MWe
Mirror reflectivity	90%	94%
Field efficiency	73%	73%
Mirror cleanliness	95%	95%
Receiver efficiency	87%	87%
Storage efficiency	99%	99%
Electromechanical conversion efficiency of generator	34%	43%
Auxiliary components efficiency	90%	93%
Overall solar-to-electric conversion efficiency	16%	23%

(Source: U.S. Department of Energy and Southern California Edison Company.)

Major Conclusions of the studies to date

- First plants as large as 100–200 MW_e are possible to design and build based on the demonstrated technology to date. Future plants could be larger.
- The plant capacity factors up to 65 percent are possible, including outage.
- Fifteen percent annual average solar-to-electric conversion efficiency is achievable.
- The energy storage feature of the technology makes possible to meet the peak demand on the utility lines.

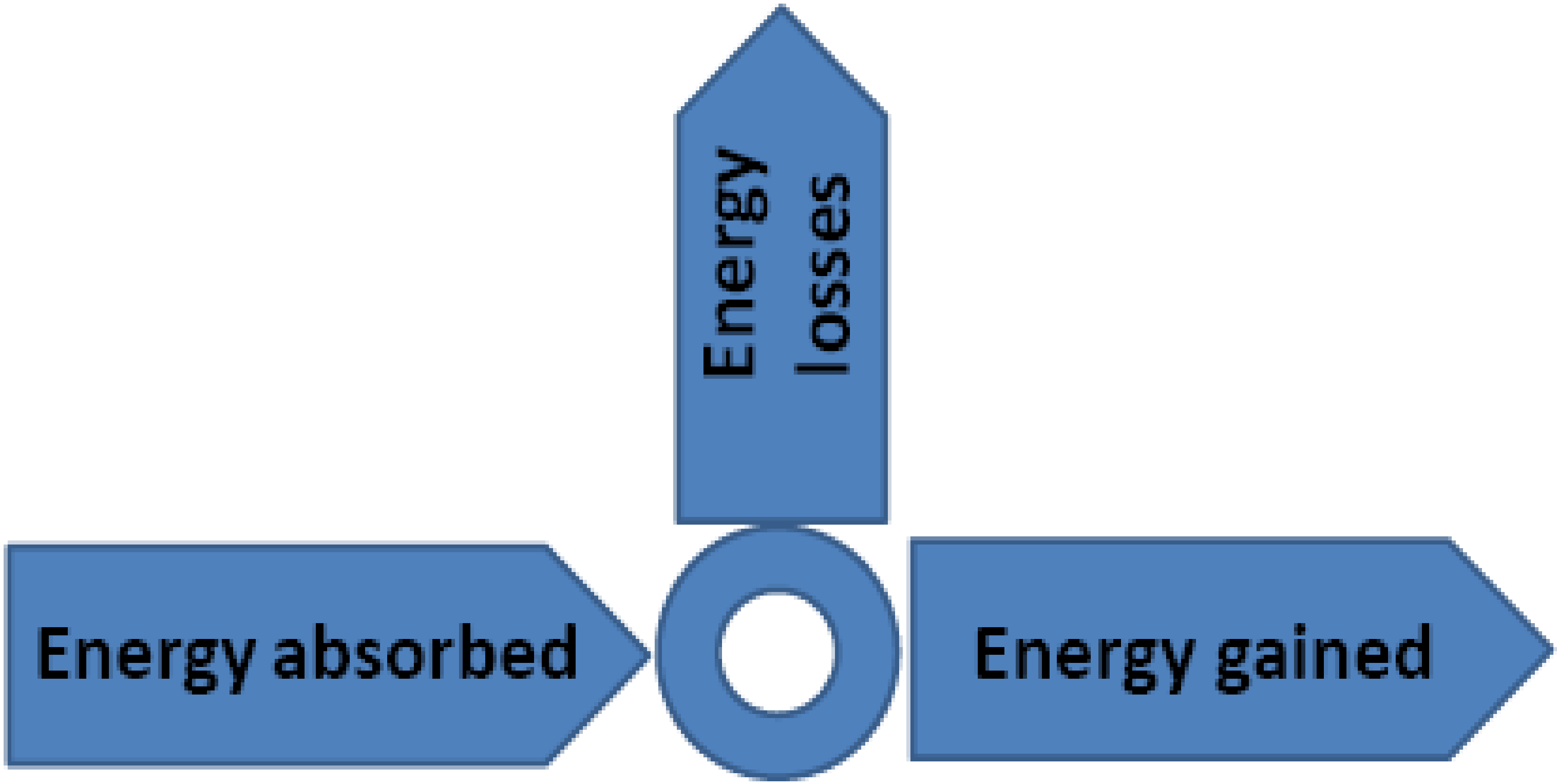
Major Conclusions of the studies to date

- Leveled energy cost is estimated to be 6 to 7 cents per kWh.
- A 100 MW_e plant with a capacity factor of 40 percent requires 1.5 square miles of land.
- The capital cost of $2,000 per kW_e capacity for first few commercial plants and less for future plants.
- A comparable combined cycle gas turbine plant would cost $1,000 kW_e, which includes no fuel cost.
- Solar-fossil hybrids are the next step in development of this technology.

Parabolic Dish

- The parabolic dish tracks the sun to focus heat, which drives a sterling heat engine-generator unit.
- This technology has applications in relatively small capacity (tens of kW) due the size of available engines and wind loads on the dish collectors.
- Because of their small size, it is more modular than other solar thermal power systems, and can be assembled in a few hundred kW to few MW capacities.
- This technology is particularly attractive for small stand-alone remote applications.

The useful energy



Thank You
For Your Attention