Performance Analysis of Hillside Solar Tower Systems

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Introduction

Concentrated Solar Power "CSP"

The concept of concentrated solar power "CSP" is to increase useful solar energy utilization by using a large area of reflectors to reflect and concentrate solar irradiation on a relatively small central receiver. This concentrated irradiation is then extracted by an appropriate fluid called heat transfer fluid (HTF) and carried to be utilized in either thermal or electrical applications.

Solar Central Tower is a CSP technology. CSP technologies also include solar dish, linear Fresnel and parabolic trough.

The central tower system is considered an expanded form from the solar dish, where the receiver is placed on a point somewhere on the tower and the parabolic dish is replaced and expanded on the ground by a group of distributed reflecting elements called heliostats. Three types of heliostat fields are mentioned in the literature: Parallel Staggered Cornfield distribution, Radial staggered distribution and Phyllotaxis spiral distribution.

Hillside Solar Central Tower System

The concept of a hillside solar tower system is to use a hillside to host the heliostat field. In this manner, the cost of used land is reduced and the problem of flat land availability for CT systems is solved. Also, Hillside CT systems offer an option to use an adjacent hill to locate the tower. This way hill elevation is utilized to reduce the cost of the tower by using a smaller one.

Results and Conclusions

▪Annual total field efficiency decreases as the heliostat field tilt angle increases.

▪The field area decreases with increasing field tilt angle for small field tilt angle values, then increases with larger values.

▪The minimum field area was associated with a 15o tilt angle for the studied system.

▪Annual total field efficiency increases with increasing tower height until they reach a peak value. Afterward, they decrease because of the reduction in attenuation and interception efficiencies

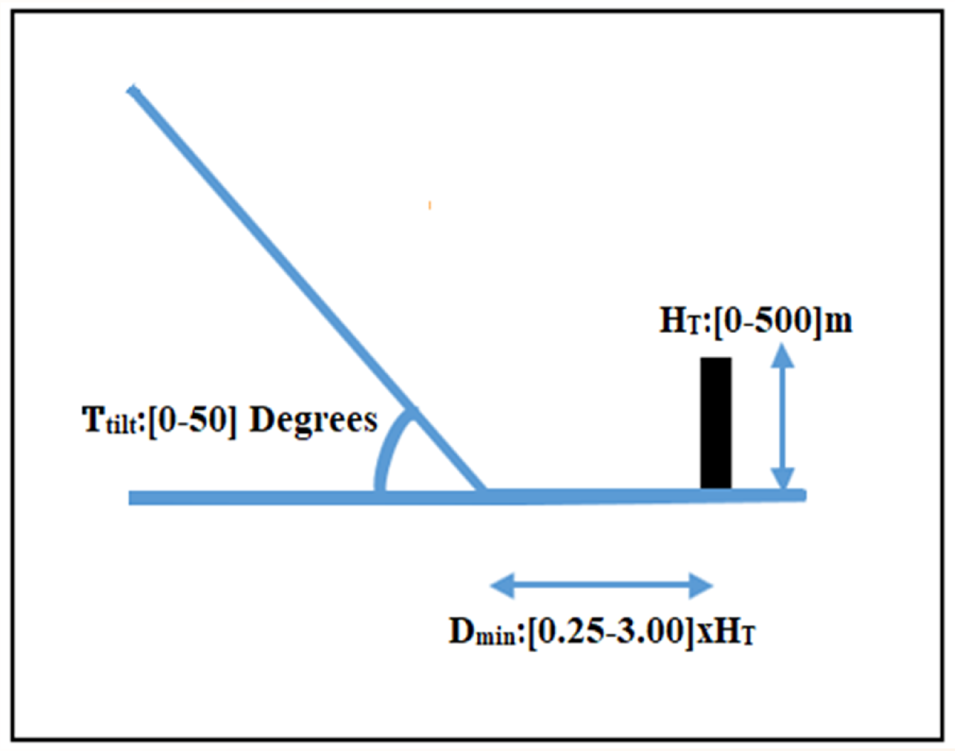
▪The shorter the distance between tower and heliostat field is the better in performance, with higher optical efficiencies, a lower number of heliostats, and less land use.

Aim of the Study

In this work, two additional novel ideas are added to the attempts for improving the solar tower system performance. The concept of spiral hillside heliostat field distribution and the effect of geometric parameters that control the field distribution on system performance.

Three geometric parameters that have been investigated to achieve maximum optical efficiencies:

- Heliostat field slope.
- Field distance from the tower.
- Tower height.

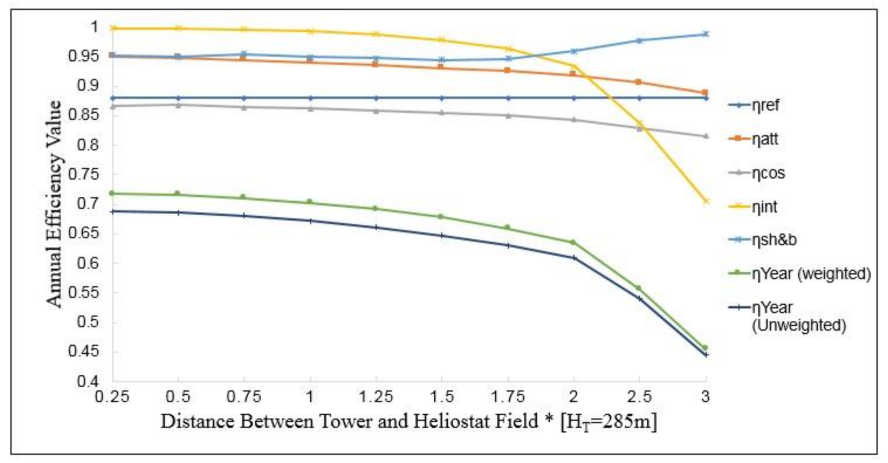


Solar Field Performance

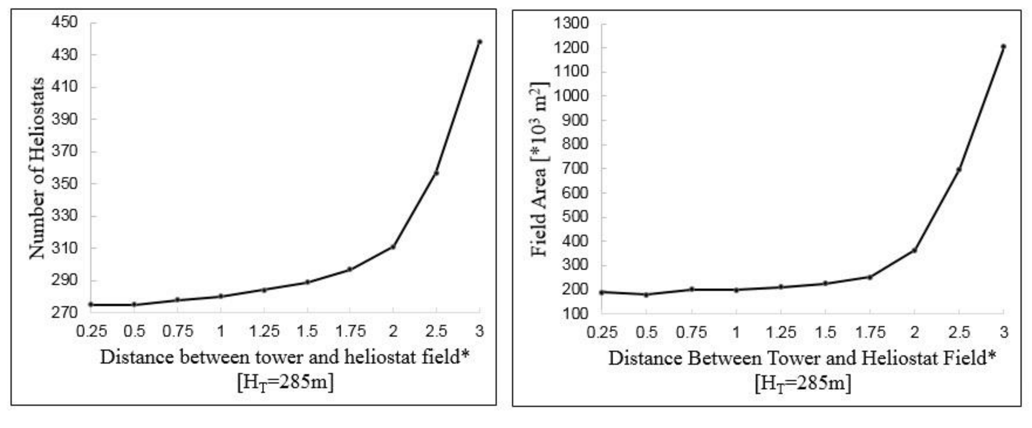
- This study was performed numerically using a developed MATLAB code which was validated against known data in the literature.
- Spiral distribution was used to allocate locations of heliostats in the field.
- Particle Swarm Optimization (PSO) method was used to achieve optimum filed distribution with maximum annual weighted field efficiency.
- All loss sources are included for simulation using heliostats individually basis study.
- The studied system is assumed to generate 25 MW thermal power using Planta Solar 10 heliostat field parameters at the location of Sierra Sun Tower in California, USA.
- System parameters are described in the following table. The system is designed to generate 25 MW thermal power on the design time which is on March 21 at noon.

Receiver Type	Cavity	**Heliostat height** H_h	9.45 m
Aperture Height	12 m	**Heliostat width** W_h	12.84 m
Aperture Width	13.78 m	**Slop error** σ_{sl}	0 $mrad$
Receiver Tilt Angle	12.5°	**Tracking error** σ_{tr}	2.90 $mrad$
Optical Tower Height	[0-500] m	**Sun shape error** σ_{sun}	2.51 $mrad$
Heliostat shape	Rectangular	**Location Latitude**	34.733 N
D_{min}	[0.25-3.00]*H_T	**Location Longitude**	118.14 W
T_{tilt}	[0-50] Degree	**Location Altitude**	707 m

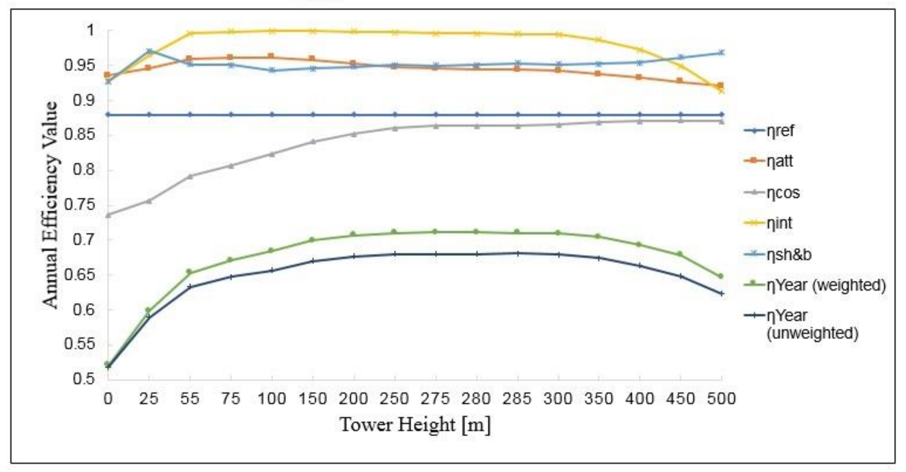
Annual Optical Efficiencies vs. D_{min};
τ_{tilt}=15° and H_T=285 m



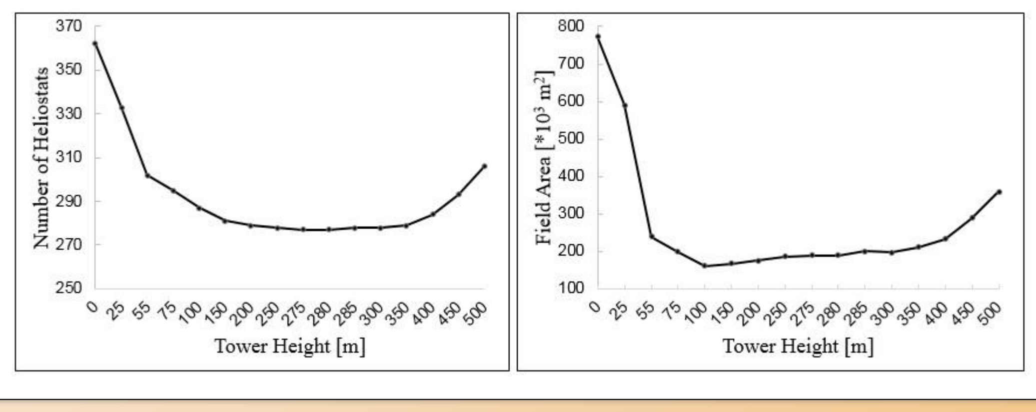
Number of Heliostats vs. D_{min} and Field Area vs. D_{min};
τ_{tilt}=15° and H_T=285 m



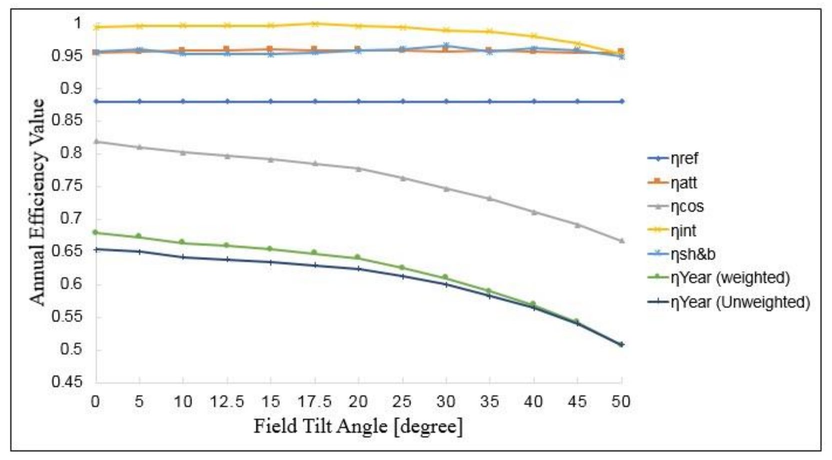
Annual Optical Efficiencies vs. H_T;
D_{min}=0.75* H_T and τ_{tilt}=15°



Number of Heliostats vs. H_T and Field Area vs. H_T;
D_{min}=0.75* H_T and τ_{tilt}=15°



Annual Optical Efficiencies vs. τ_{tilt};
H_T=55 m and D_{min}=0.75* H_T



Number of Heliostats vs. τ_{tilt} and Field Area vs. τ_{tilt};
H_T=55 m and D_{min}=0.75* H_T