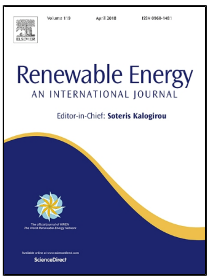
Accepted Manuscript



Optimal Solar Tree Design for Increased Flexibility in Seasonal Energy Extraction

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PII:	S0960-1481(18)30160-5
DOI:	10.1016/j.renene.2018.02.017
Reference:	RENE 9748
To appear in:	*Renewable Energy*
Received Date:	05 October 2017
Revised Date:	29 December 2017
Accepted Date:	02 February 2018

Please cite this article as: Sumon Dey, Madan Kumar Lakshmanan, Bala Pesala, Optimal Solar Tree Design for Increased Flexibility in Seasonal Energy Extraction, *Renewable Energy* (2018), doi: 10.1016/j.renene.2018.02.017

Optimal Solar Tree Design for Increased Flexibility in Seasonal Energy Extraction

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Abstract

The paper proposes location/application specific tuning of the solar power generation curve by appropriately orienting solar panels in a solar tree. The initial part of the study involving optimization of single panel orientation, emphasizes the need to adopt data driven approach. Study carried out for 15 locations covering a large latitude range shows that optimal orientation cannot be determined based on the latitude angle alone and azimuth angle also needs to be considered, especially for locations having asymmetric solar insolation pattern during a day. Based on these insights, feasibility of tuning annual solar power generation curve is shown by designing a 1 kW solar tree for four locations. Genetic algorithm based optimization is used for positioning of the solar panels so that shadow losses are minimized. Validation with ray optic simulations for solar trees designed for two locations have shown less than 2% shading losses. The optimized solar trees for San Francisco and Paris show increase in power generation of 2.04% and 7.38% respectively compared to latitude tilt. The simulations are further validated using a scaled down prototype solar tree showing excellent match. The methodology presented here can be easily extended to the design of optimized solar tree for any location and capacity.

Keywords: Solar Tree; Solar Panels; Optimal Orientation; Data Driven Optimization; Power Generation Curve; Shadow Analysis

1. Introduction

Renewable energy sources are vital to meet the energy demand of the future with solar photovoltaics being one of the prime sources due to abundant availability of solar energy. In order to obtain maximum power from the Sun, it is essential that the solar panels are oriented so as to focus the Sun rays on its surface. This can be achieved by tracking the Sun continuously. However, tracking systems which involve large moving parts have certain disadvantages due to structural instability concerns, especially at high wind velocities, reduced life of the system and also increased maintenance cost [1]. Therefore, solar panels with fixed orientation or with minimal seasonal adjustments are preferred to obtain maximum annual average solar irradiation.

A number of studies have been conducted to find the annual optimal tilt angle for different locations. H. Moghadam et al. suggested that annual optimal tilt angle is close to latitude of the location for latitudes ranging from 0^0 to 60^0 and is given by the regression model $0.917\ \varphi + 0.321$ [2]. Darhmaoui et. al. [3] developed a latitude based model $1.25\ \varphi - 0.007\ \varphi^2$ for the determination of optimal tilt angle for the Mediterranean region. Cheng et. al. [4] conducted a study for 20 different locations ranging 0^0 to 85^0 N and

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