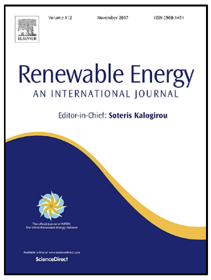
Accepted Manuscript



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PII:	S0960-1481(17)30650-X
DOI:	10.1016/j.renene.2017.07.037
Reference:	RENE 9012
To appear in:	*Renewable Energy*
Received Date:	20 June 2016
Revised Date:	17 April 2017
Accepted Date:	10 July 2017

Please cite this article as: S. Glynn John, T. Lakshmanan, Cost Optimization of Dish Solar Concentrators for Improved Scalability Decisions, *Renewable Energy* (2017), doi: 10.1016/j.renene.2017.07.037

Cost Optimization of Dish Solar Concentrators for Improved Scalability Decisions

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Abstract

Solar thermal power plants using dish-engine systems have conventionally used multiple dishes of an optimum size. In a few recent developments, dish sizes up to 500m² have been attempted in order to scale up power generation. Although using very large dishes may have a few advantages, the cost implications need to be analyzed before implementing such designs. An optimum dish size may provide the key advantage for dish-engine power plants to compete with grid power, but determining it poses a serious challenge. As dish-engine power plants call for heavy investments, it becomes important to design dishes to endure excessive wind loads, to prevent an overnight obliteration. A simple cost model is presented in this paper, in which the structural problem is modeled mathematically and optimized for minimum cost subject to wind-load resistance constraints. This paper demonstrates how cost optimization can be used as an effective decision making tool for selecting the right dish size. The optimization results indicate that very large dishes of conventional designs may not be cost-effective if they have to withstand heavy wind loads.

Keywords: Optimization, Cost-optimization, Dish-Concentrator, Dish-Engine.

1. Introduction

Dish solar concentrators provide one of the highest concentration ratios among the available solar concentrators and hence higher focus temperatures and better efficiencies with different thermodynamic cycles [8, 11]. Power generation systems using dish concentrators of various sizes have been developed over the years in different parts of the world [1, 5, 7]. It is true that as the size of the concentrator increases, higher temperatures are possible with higher power output, but does it mean that the concentrators should become extremely large for scaling up of power generation? In the past two decades, the dish-concentrators have increased in size and have reached the size of 500m² [10]. It is obvious that as the size of a concentrator increases, the structural complexity and the handling costs also increase. But, the most important question in the mind of the designer is, what is the optimum dish size for maximum power at minimum cost?

Power generation using solar dish concentrators is more than a century old starting from Abel Pfire's printing press [16]. Large scale experimentation in electrical power generation started in the late 70's and continue till date. The Solar Total Energy System project was a large scale experiment started in 1977, in which 7m diameter dishes were installed at the site of a knitting wear manufacturer for supplying electricity and process steam in Shennadoah, Georgia, USA. The dish structure was made of steel and the reflecting surface was made of a 3M reflecting polymer pasted on die-stamped aluminum petals. The power generation system consisted of a steam turbine supplied with steam from all the individual receivers [5]. Dish concentrators with Stirling engine power generation systems were installed and tested by different organizations during the 80's and 90's with diameters from 7.5m to 17m and net electricity generation ranging from 7.5 to 52.5 kW [7].

White Cliffs solar power station in Australia was designed and constructed by a team from the Australian National University (ANU) in 1981. The station had 14 dishes of 20m² aperture area, with the reflecting surface made of multiple glass mirrors of size 100mmX100mm glued to the paraboloidal dishes. The dishes were used to generate steam for driving a three cylinder steam engine coupled to a generator. The ANU research team built a 400m² solar dish concentrator prototype in 1994. The dish was used for producing 50kW of electrical power using a grid connected steam engine-generator [10]. The mass of the Dish was 19 tons, and the foundations weighed 50 tons, the shape of the dish was hexagonal. A second dish of 500m² aperture area was completed on the ANU campus in 2009, the total mass of dish was 19.1 tons and the base and supports weighed 7.3 tons, the shape was close to octagonal [1].

An approach was presented in Refs. [3, 4, 5] for optimization of dish concentrators used in Shennadoah. A dish size of 7m diameter was selected after optimizing the various performance metrics such as strength, efficiency and resistance to