Design of Solar Thermal Systems

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Preface

This book presents the design of solar thermal systems using mathematical modeling. The importance of mathematical modeling is continuously increasing because of the rapid spread in the use of computers as design tools. The book is thus prepared for those who are involved in the design, optimization, or evaluation of the performance of solar thermal systems.

The book is based on teaching notes for undergraduate and first year graduate courses for thermal engineering students. It is recommended as a text for senior undergraduate students or first year graduate students, and also as a reference book for engineers working in various solar thermal applications.

The book consists of 10 chapters. The first chapter reviews the world resources of energy and their classification and relation to solar energy. The second chapter reviews important topics in thermal radiation which are relevant to the subject of the book. The third chapter is concerned with the estimation of solar angles and the hourly, daily, and monthly average daily solar radiation. Mathematical equations are given to enable the designer of a solar thermal system to estimate the beam, diffuse, or total radiation on horizontal or tilted surfaces.

The transmission of solar radiation through transparent sheets of different material is treated in Chapter 4. This chapter gives mathematical equations to predict the radiation properties of multi-layer partially transparent sheets with or without an absorber plate. A computer program is included to enable the designer to estimate the radiation properties for several geometries of a stack of similar or nonsimilar transparent sheets with or without an absorber plate at any incidence angle. The program is useful in the design and optimization of flat plate collectors and solar concentrators, and can also be utilized by air conditioning engineers to estimate solar heat gain through transparent windows and doors.

Chapter 5 gives the design of flat plate collectors, and presents various types. Complete simulation of the collectors is given, and the various factors affecting their performance are discussed. A computer program is given to design and optimize the design parameters of the flat plate collectors. This program can also be used to evaluate the performance of flat plate collectors in off-design conditions.

Chapter 6 deals with solar desalination. The chapter will be helpful to those designing either roof-type or diffusion-type solar desalination systems, since it includes a more detailed description of these systems than most other solar energy text books. Analysis are given to predict the transient performance of the roof-type still. A computer program is given to assist the designer in predicting the effect of various design and operating conditions on the performance of the still. Various novel designs of roof-types stills are presented with the advantages and disadvantages of each. The chapter also gives the analysis of both the single effect and the multiple-effect diffusion-type still together with a brief presentation of the mass diffusion theory. Other methods of solar desalination are also discussed in the chapter.

The collection of solar energy at medium and high temperatures by solar concentrators is discussed in Chapter 7. Various types of concentrators are presented. Thermal analyses are given to show the important factors affecting the performance of solar concentrators. Different tracking modes are given. The material in this chapter will help the reader to select the type of solar concentrator most suitable for a particular application together with the adequate tracking mode. Details of the designing of intermittent tracking are given in the chapter. Readers interested in continuous tracking will find ample material in section 10.8 of Chapter 10.

In Chapter 8, the design of solar energy storage is considered. The first part of the chapter deals with storage methods, characteristics, location, and the evaluation of the storage process. Mathematical simulations of various types of sensible heat storage are carried out for low, intermediate, and high temperature applications. In particular, mathematical simulations are presented for the transient performance of the mixed liquid storage, underground liquid storage, and stratified liquid storage. With these simulations the reader of the chapter should be able to size the liquid storage tank required for a certain application. Designers of solid storage tanks will also find that the mathematical simulation of rock bed storage and its sizing are covered in the chapter. In addition, other techniques of solar energy storage such as low, intermediate, and high temperature phase change and chemical and mechanical storages are considered. The user of the simulation models given in this chapter should have a reasonable background in the finite difference numerical technique.

The solar-operated absorption cooling system is treated in Chapter 9. Both H_2O-LiBr and NH_3-H_2O absorption systems are considered. Different arrangements of solar-operated absorption cooling systems are given, together with the criteria to evaluate and compare these systems. Alternative combinations of absorption cooling systems, such as the dual series connected system and the two stage absorption cooling system, are presented. Mathematical simulations of both the H_2O-LiBr and NH_3-H_2O absorption machines are considered. A computer program is included to predict the performance of the absorption cooling machine in various design and operating conditions. An optimization procedure is given for the determination of the design parameters of the absorption cooling machine. The chapter also contains a brief description of the intermittent absorption cooling system.

Chapter 10 deals with solar power generation. The chapter includes the characteristics required for the working fluids of the solar-operated Rankine cycle. Mathematical simulation is given for the Rankine cycle and selection of the various design parameters of the system is presented. The chapter also includes the performance of the solar-operated Rankine cycle (SORC) in various operating conditions. In addition, the engineering considerations for the selection of the various components of SORC are given. Analyses are also presented to select the optimum collector temperature for solar-operated power cycles. A sizeable section of the chapter is devoted to power tower technology, including material for the determination of the heliostat field layout, the determination of the tilt and orientation angle of each heliostat, and the sizing of the receiver.

The book adds considerably to engineering expertise in the design of solar thermal systems. Chapters 5 and 8 are relevant to the design of solar water heaters, swimming pool heating systems, and space heating. Chapter 6 will also assist in the design of solar desalination systems. Those involved in the design of solar operated absorption cooling systems should read Chapter 9 in addition to Chapter 8 and Chapters 5 or 7. Information on solar power generation is given in Chapter 10 and also in Chapters 7 and 8.

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Jeddah
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Appendices

Solar thermal systems differ from solar photovoltaics which convert sunlight directly into electricity. The use of the term 'solar thermal' is also associated with the integration of 'passive' heating and cooling technologies in buildings. The UK offers a good climate for solar thermal systems benefiting from around 60% of the solar energy that is received at the equator and similar amounts to other northern European states.Â A properly designed and installed solar thermal system can maximise the capture of this power and translate 60% of it into useful energy for hot water. Solar systems have a number of positive attributes that are likely to promote greater use in the UK Solar thermal systems used for both space heating and domestic hot water are becoming more popular within the residential market; however, when using only diurnal storage these systems typically are unable to achieve solar fractions greater than 50% [31]. To increase the solar fraction of these systems a seasonal thermal storage system is required. When seasonal thermal storage systems are successfully implemented an annual solar fraction approaching 100% is obtainable [30]. To meet these high solar fractions, significant storage capacity is required, with seasonal thermal storage systems havi Storing solar heat (thermal batteries): If you incorporate thermal mass into a home to store and release heat, you can distribute the heat collected over a longer period of time, and there are any number of creative ways to do this. Sticking with the DIY theme for say - sheds, garages or greenhouses, you could run the heated air through tubes embedded in sand, bricks, masonry etc before venting it directly into the conditioned space.Â Web searches reveal an endless list of designs and assembly techniques for DIY solar air heaters, the same holds true for DIY videos on YouTube. Different designs will resonate differently with different people, so pick the one that best suits your skill set, tool collection and attention span.