Software Requirements Specification for Sun Catcher

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Contents

Revision History

Date	Version	Notes
2019/10./16	1.0	First version of SRS update to GitHub
Date 2	1.1	Notes

1 Reference Material

This section records information for easy reference.

1.1 Table of Units

Throughout this document SI (Système International d'Unités) is employedas the unit system. In addition to the basic units, several derived units are used as described below. For each unit, the symbol is given followed by a description of the unit and the SI name.

symbol	**unit**	**SI**
$^\circ$	angle	degree
$'$	angle	-
k	mass	kilograms
m	length	metre
W	power	Watt ($\mathrm{W} = \mathrm{J\,s^{-1}}$)

1.2 Table of Symbols

The table that follows summarizes the symbols used in this document along with their units. The choice of symbols was made to be consistent with the heat transfer literature and with existing documentation for solar water heating systems. The symbols are listed in alphabetical order.

symbol	**unit**	**description**
$\theta_{S_{\text{day}}}$	$^\circ$	zenith angle of sun in the day
θ_T	$^\circ$	the tilt angle for adjusting the solar panel
Φ_P	($^\circ$, $'$)	the latitude of the solar panel
δ_{date}	($^\circ$, N/S)	the daily declination of the vertical noon sun in the date duration
I_S	$\frac{\mathrm{kW}}{\mathrm{m}^2}$	the intensity of the sun measured by the satellites
$I_{S_{\text{daily}}}$	$\frac{\mathrm{kW}}{\mathrm{m}^2}$	the daily solar intensity of the noon in the date duration(*date*).
$I_{S_{\text{total}}}$	$\frac{\mathrm{kW}}{\mathrm{m}^2}$	the total solar intensity of the noon in the date duration(*date*).
$I_{S_{\max}}$	$\frac{\mathrm{kW}}{\mathrm{m}^2}$	the hightest solar intensity of the noon in the date duration(*date*).
P_E	kW	the estimated solar panel output energy
$P_{A_{\text{h}}}$	m^2	the height of the solar panel
$P_{A_{\text{w}}}$	m^2	the width of the solar panel
P_{r}	%	solar panel yield or efficiency
PR	%	performance ratio, coefficient for losses

date	-	the date duration between the calculation starting date and the ending date
$year_{\text{Start}}$	-	the year of the calcuation's starting date
$month_{\text{Start}}$	-	the month of the calcuation's starting date
day_{Start}	-	the day of the calcuation's starting date
$year_{\text{End}}$	-	the year of the calcuation's ending date
$month_{\text{End}}$	-	the month of the calcuation's ending date

1.3 Abbreviations and Acronyms

symbol	**description**
A	Assumption
DD	Data Definition
GD	General Definition
GS	Goal Statement
IM	Instance Model
LC	Likely Change
PS	Physical System Description
R	Requirement
SRS	Software Requirements Specification
SC	Sun Catcher
T	Theoretical Model

2 Introduction

Due to the increasing concepts of creating an earth-friendly environment, the kits using renewable energy becomes more popular in the market. Solar energy is the most common type of renewable resource for a home. However, it is an expensive technology, and its cell efficiency is restricted by seasons. Therefore, Sun Catcheris created for home users to gain optimum energyfrom daily sunlight.

The following sections provide an overview of the Software Requirements Specification (SRS) for Sun Catcher(SC). This section explains the purpose and the organization of the document, the scope of the requirements, and the characteristics of the intendedreader.

2.1 Purpose of Document

The purpose of this document is to record the correct requirements of SC. The goal statement provided readers a consistent idea of what problem is solved. Thetheoretical models and the instance models, which state the mathematical terms supporting the theoretical models, are explained unambiguously for readers to reuse and verify the software. In the section of System Constraints, its contents will stay abstract because the content should only say what problem is being solved, but not how to solve it.

This document will be used as a starting point for subsequent development phases, including writing the design specification and the software verificationand validation plan. The design document will show how the requirements are to be realized, includingdecisions on the numerical algorithms and programming environment. The verification and validation plan will show the steps that will be used to increase confidence in the software documentation and the implementation.

2.2 Scope of Requirements

The scope of the requirements includes stability analysis of a two-dimensional (2D) solar panel and the sun as the solar resource. The solar panel is assumed to place in a location near sea level, and the sky view above is unobstructed, with no trees, hills, clouds, dust, or haze ever blocking the sun.

2.3 Characteristics of Intended Reader

This section summarized the expectation of the readers' knowledge and skills forunderstanding this SRS. Readers should have a general knowledge of how a solar panel works and know the common factors that affect energy absorption.

2.4 Organization of Document

The organization of this document follows the template for an SRS for scientificcomputing software proposed by [1] as well as [2]. The presentation follows the standard pattern of presenting goals, theories, definitions, and assumptions. For readers that would like a more bottom up approach, they can start reading the instance models in Section: Instance Models) and trace back to find any additional information they require. The goal statements (Section: Goal Statements) are refined to the theoretical models and the theoretical models (Section: Theoretical Models) to the instance models (Section: Instance Models). The instance models provide the set ofalgebraic equations that must be solved.

3 General System Description

This section provides general information about the system. It identifies the interfaces between the system and its environment, describes the user characteristics and lists the system constraints.

3.1 System Context

System Context shows the design pattern of this program from users to the system then the output. The circle represents the users of this software. The rectangle represents the software system: Sun Catcher(SC). The arrow represents the inputsthat drive the software and the output expecting from the software system.

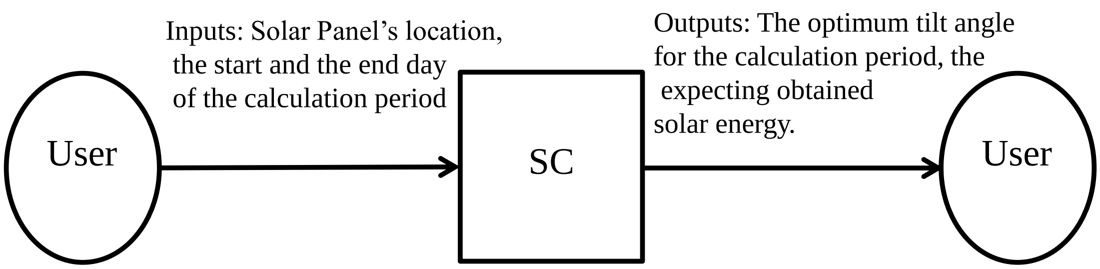

Figure 1: System Context

- User Responsibilities:
  - Provide the input data related to the solar panel.
  - Ensure the input date format matches the requirement from SC.
  - Ensure the condition of the solar panel, and the surrounding environment of the solar panel.
- SC Responsibilities:
  - Detect data type mismatch, such as a string of characters instead of a floating point number.
  - Comfirm the inputs quality to satisfy the required physical and software constraints.
  - Predict an optimum tilt angle and the expected gaining solar energy, and show the result explicitly to users (such as generating a report with linear graphic).

3.2 User Characteristics

The end-users of SC is expecting to understand the Level 1 Calculation method such as angle addition and subtraction theorems and understand the Level 1 celestial mechanics such as the formation of the latitude and the earth's tilt angle in the four seasons.

3.3 System Constraints

There are no system constraints.

4 Specific System Description

This section first presents the problem description, which gives a high-level view of the problem to be solved. This is followed by the solution characteristics specification, which presents the assumptions, theories, definitions and finallythe instance models.

4.1 Problem Description

Sun Catcheris intended to solve the unpredictable energy efficiency of solar panels. Due to the tilt angle of the earth when it rotates by axis, the latitude of the sun will consistently move. With the fixed location of the solarpanel, it is unlikely to get the direct the direct sunlight for the maximumoutput. Therefore, it causes inadequate performance in gaining energy.

4.1.1 Terminology and Definitions

This subsection provides a list of terms that are used in the subsequent sections and their meaning, with the purpose of reducing ambiguity and making iteasier to correctly understand the requirements:

- Declination of the Sun: The angle between the rays of the Sun and the plane of the Earth's equator.
- Tilt angle: The angle for adjusting the solar panel result in the panel get the direct sunlight. According to the Figure:The Physic System, tilt angle is equal to the zenith angle.
- The period of days: The period of days depends on the input days of the users.
- Sun panel: The adjustable panel, which has solar cells on it, able to converse solar energy to power.
- Solar intensity: The amount of incoming solar energy, or radiation, that reaches the Earth's surface.

- Latitude: The angle which ranges from 0 ° at the Equator to 90° (North or South) at the poles.
- Zenith Angle: The angle between the sun and the vertical. According to theFigure:The Physic System, zenith angle is equal to the tilt angle.

4.1.2 Physical System Description

The physical system of SC, as shown in Figure: *ThePhysicSystem*, includes the following elements:

PS1: Solar panel, the panel with solar cells that able to absorb solar energy from the sun.

PS2: Sun, proving solar energy to the solar panel

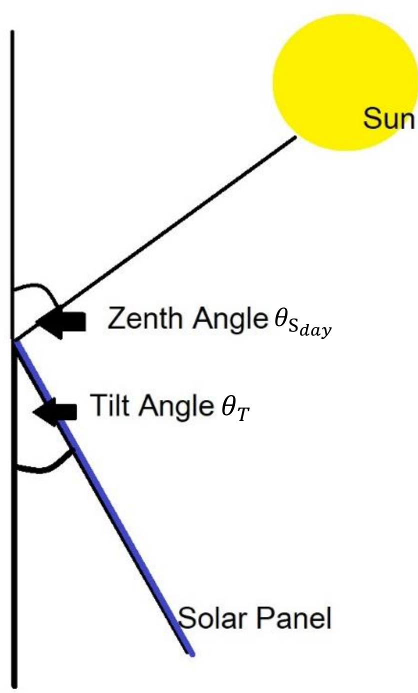

Figure 2: The Physic System

4.1.3 Goal Statements

Given the user located latitude(Φ_P), the area of the solar panel(P_A), the day started to estimate angle(day_{Start}),the day when the estimation end(day_{End}), the goal statements are:

GS1: Predict the optimum tilt angle in the period of days(θ_T).

GS2: Predict the optimum produced solar energy in the period of days(P_E).

4.2 Solution Characteristics Specification

The instance models that govern SC are presented in Section: Instance Models. The information to understand the meaning of the instance models and their derivation is also presented, so that the instance models can be verified.

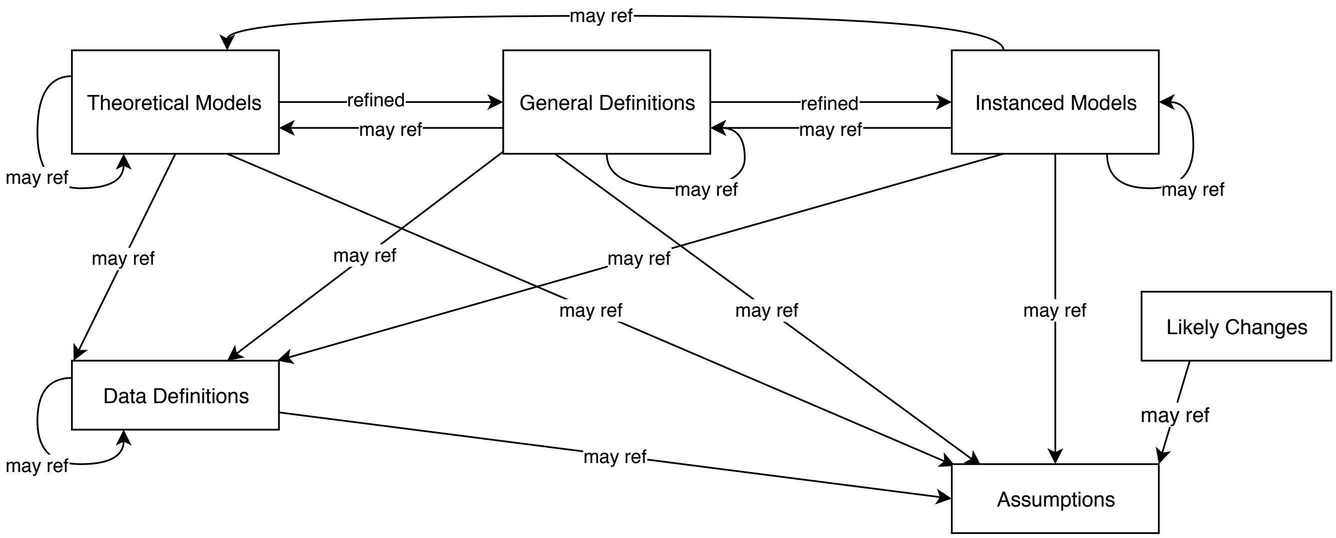

Figure 3: Models' Relations

The instance models that govern SC are presented in Subsection 4.2.5. The information to understand the meaning of theinstance models and their derivation is also presented, so that the instance models can be verified.

4.2.1 Assumptions

This section simplifies the original problem and helps in developing the theoretical model by filling in the missing information for the physical system. The numbers given in the square brackets refer to the theoretical model [T], general definition [GD], data definition [DD], instance model [IM], or likely change [LC], in which the respective assumption is used.

A1 : The environmentalcondition of the solar panel location assumed as users have an unobstructed viewof the sky, with no trees, hills, clouds, dust, or haze ever blocking the sun.(RefBy: GD1)

A2 : The default value of solar intensity(I_S) is provided in Section: Values of Auxiliary Constants.(RefBy: GD1)

A3 : This system calculate the solar zenith angle at noon.(RefBy: DD2)

A4 : Based on the resource of [3], this system definite the variable of P_r is refine by.(RefBy: IM3 and Values of Auxiliary Constants)

A5 : Based on the resource of https://photovoltaic-software.com/principle-ressources/how-calculate-solar-energy-power-pv-systems, this system definite the variable of PR is refine by.(RefBy: IM3 and Values of Auxiliary Constants)

A6 : Based on the resource of [4], the value of θ_T is refine by: IM1 and Output Variables

A7 : Based on the label of every solar panel, the value of P_E is refine by: IM3and Output Variables

4.2.2 Theoretical Models

This section focuses on the general equations and laws that SC is based on.

Number	T1
Label	**Lambert's cosine law**
Equation	$I_0 = I \times \frac{\cos\theta \times \partial\Omega \times \partial A}{\cos\theta \times \partial\Omega_0 \times \partial A_0}$
Description	In the following source, Lambert's cosine law state that "the radiant intensity or luminous intensity observed from an ideal diffusely reflecting surface or ideal diffuse radiator is directly proportional to the cosine of the angle θ between the direction of the incident light and the surface normal." I_0 is the radiance of illumination. I is the number of the photons. $\cos\theta \times \partial\Omega \times \partial A$is the number of photonsper second emitted into the wedge at angle θ where $\partial\Omega$is an equal angle that represents each wedge in the circle. ∂A is the area element . $\partial\Omega_0$ is the portion of the observer's total angular field-of-viewof the scene. ∂A_0 is an aperture of area .
Source	[5]
Ref. By	GD1

4.2.3 General Definitions

This section collects the laws and equations that will be used in building the instance models.

Number	GD1
Label	**Calculating the Solar intensity**
SI Units	$\theta_{S_{\text{day}}}$
Equation	$I_{S_{\text{total}}} = I_S \cdot \frac{1.00}{I_S}^{sec(\theta_{S_{\text{day}}})}$
Description	This equation is calculating the total solar intensity in the date duration ($\theta_{S_{\text{day}}}$) is the zenith angle of the sun in the day. It is input from $DD2$. I_S is solar intensity. Its default value has described in the Assumption: A2.
Sources	https://www.solarpaneltilt.com/#other[4]
Ref. By	IM1

Derivation of simplified the calculation of total solar intensity

The above equation is driven by the $T1$, which is describing the calculation of the radiance of the illumination.
This formula assumes that the earth is flat, so a factor was applied to account for the curvature of the earth (and therefore the earth's atmosphere). These factors and the angle of the sun with respect to the panel represent as $\frac{1.00}{I_S}^{sec(\theta_{S_{\text{day}}})}$
Where $\frac{1}{\cos\theta_{S_{\text{day}}}}$ is $sec(\theta_{S_{\text{day}}})$

4.2.4 Data Definitions

This section collects and defines all the data needed to build the instance models. The dimension of each quantity is also given.

Number	DD1
Label	**The Declination of the Sun**
Symbol	δ_{date}
SI Units	$^\circ$
Equation	-
Description	'date' defines in the table: Table of Symbols and refer from DD3. The degree of δ_{date} can be determined by Figure: Analemma.
Sources	https://www.cengage.com/resource_uploads/downloads/0495555061_137179.pdf
Ref. By	DD2

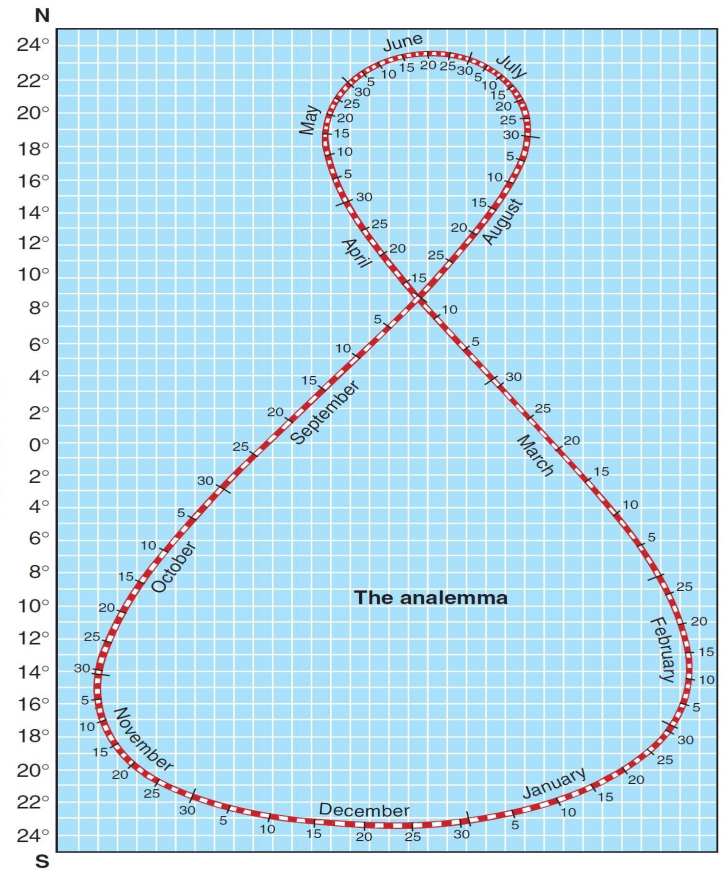

Figure 4: Analemma

Number	DD2
Label	**Calculate Zenith Angle**
Symbol	$\theta_{S_{\text{day}}}$
SI Units	$\circ$
Equation	$$\theta_{S_{\text{day}}} = \begin{cases} \Phi_P - \delta_{\text{date}}, & \text{if } 0 \le \Phi_P, \delta_{\text{date}} \le 90°\text{N} \ \vee \ 0 \le \Phi_P, \delta_{\text{date}} \le 90°\text{S} \\ \Phi_P + \delta_{\text{date}}, & \text{if } \begin{cases} 0 \le \Phi_P \le 90°\text{N} \ \wedge \ 0 \le \delta_{\text{date}} \le 90°\text{S} \\ 0 \le \Phi_P \le 90°\text{S} \ \wedge \ 0 \le \delta_{\text{date}} \le 90°\text{N} \end{cases} \end{cases}$$
Description	This equation describes the zenith angle associated with the solar panel. $\theta_{S_{\text{day}}}$ is the zeith angle of the sun in the day. Φ_P is the local latitude of the solar panel from the users' input described at Goal Statements. δ_{date} is the declination of the vertical noon sun in the day. It is input from DD1
Source	[6]
Ref. By	GD1

Detailed derivation of simplified the calculation of zenith angle

According to the resource [6], it states the the solar elevation angle $\sin\alpha$ is determined by the relationship
$\sin\alpha = \sin\Phi \times \sin\delta + \cos\Phi \times \cos\delta \times \cos \text{h}$
where
α is the solar elevation.
Φ is the latitude.
δ is the solar declination.
h is the solar hour angle.
Based on the Level 1 celestial mechanics, the solar zenith angle is equal to 90° - the solar elevation angle
which can write as
$\cos\theta = \sin\alpha = \sin\Phi \times \sin\delta + \cos\Phi \times \cos\delta \times \cos \text{h}$ Based on the Assumptions section, it assumes that SC calculate the solar zenith angle at noon which mean solar hour angle = 0°.
Therefore, $\cos \text{h} = 0$
Rewrite the equation as,

$\cos\theta = \sin\alpha = \sin\Phi \times \sin\delta + \cos\Phi \times \cos\delta \times 1$
$\Rightarrow \cos\theta = \sin\alpha = \sin\Phi \times \sin\delta + \cos\Phi \times \cos\delta$
Based on the Level 1 calcucltion, we have
$\cos\Phi \pm \delta = \sin\alpha = \sin\Phi \times \sin\delta + \cos\Phi \times \cos\delta$
Therefore, we have $\theta = \Phi \pm \delta$

Number	DD3
Label	**Calcuted the squence of the days**
Symbol	$date$
SI Units	$(year, month, day)$
Equation	$date = day_{Start} - day_{End}$
Description	day_{Start}, day_{End} are the days depending on the users' input described at Goal Statements.
Sources	-
Ref. By	DD1

4.2.5 Instance Models

This section transforms the problem defined in Section 4.1 into one which is expressed in mathematical terms. It uses concrete symbols defined in Section 4.2.4 to replace the abstract symbols in the models identified in Sections 4.2.2 and 4.2.3.

The goals Goal Statements are solved by IM1.

Number	IM1
Label	**Calculating the Tilt Angle**
Input	$\theta_{S_{\text{day}}}, I_{S_{date}}$
Output	$\theta_T, I_{S_{\max}}$ $I_{S_{\max}} = I_S \cdot \frac{1.00}{I_{S_{\text{total}}}}^{sec(\theta_{S_{\text{day}}})}$where θ_T is the valuse that has the hightest $I_{S_{\max}}$
Description	Using General Definition: GD1 can get the total solar intensity $I_{S_{date}}$ during the period od date. Then using the value $I_{S_{date}}$ recalculates the optimum angle θ_T. $I_{S_{date}}$ is input from GD1. $\theta_{S_{\text{day}}}$ is input from DD1.
Sources	https://www.solarpaneltilt.com/#other[4]
Ref. By	IM2

Number	IM2
Label	**Calculating the Daily Sun Intentisy**
Input	$\theta_{S_{\text{day}}}, I_{S_{\max}}$
Output	$I_{S_{\text{daily}}}$ $I_{S_{\text{daily}}} = I_S \cdot \frac{1.00}{I_{S_{\max}}}^{sec(\theta_{S_{\text{day}}})}$
Description	Using General Definition: GD1 can get the optimal solar intensity I_{S_T} of the date duration($date$). Then using the value I_{S_T} recalculates the optimum daily sun intensity $I_{S_{\text{daily}}}$. I_{S_T} is input from GD1. $\theta_{S_{\text{day}}}$ is input from DD1.
Sources	https://www.solarpaneltilt.com/#other[4]
Ref. By	IM3

Number	IM3
Label	**Calculating the Solar Energy Output**
Input	P_A
Output	$P_E = P_A \times P_r \times I_{S_{\text{daily}}} \times PR$
Description	P is the solar panel. P_E is the estimated solar panel output energy. P_A is the solar panel area. It is input by the users P_r is solar panel yield or efficiency. Its default value has described in the Assumption: A4. $I_{S_{date}}$ is the solar intensity in a period of days of the noon. It is input from IM1 PR is the performance ratio, coefficient for losses. Its default value has described in the Assumption: A5.
Sources	https://photovoltaic-software.com/principle-ressources/how-calculate-solar-energy-power-pv-systems
Ref. By	-

Derivation of simplify the solar energy output

The above equation is using the output from $GD1$, which is describingthe solar intensity. Some of the variable in this equation has its defult value, which describes in the section of *Assumptions*

4.2.6 Input Data Constraints

Table 1 shows the data constraints on the input output variables. The column for physical constraints gives the physical limitations on the range of values that can be taken by the variable. The column for software constraints restricts the range of inputs to reasonable values. The software constraints will be helpful in the design stage for picking suitable algorithms. The constraints are conservative, to give the user of the model theflexibility to experiment with unusual situations. The column of typical valuesis intended to provide a feel for a common scenario. The uncertainty column provides an estimate of the confidence with which the physical quantities can bemeasured. This information would be part of the input if one were performing anuncertainty quantification exercise.

The specification parameters in Table 1 are listed in Table 2.

Table 1: Input Variables

Var	**Physical Constraints**	**Software Constraints**	**Typical Value**	**Uncertainty**
Φ_P	$-90° \leq \Phi_P \leq 90°$	-	$(43°, 15'39.3")$	10%
$month$	$0 \leq month \leq 12$	-	12	10%
day	$0 \leq day \leq 31$	-	01	10%

(*)

Table 2: Specification Parameter Values

Var	**Value**
-	-

4.2.7 Properties of a Correct Solution

Table:$OutputVariables$ shows the data constraints on the output variables. The column for physical constraints gives the physical limitations on the range of values that can be taken by the variable.

Table 3: Output Variables

Var	**Physical Constraints**
θ_T	$0 \leq \theta_T \leq 90°$ (by A6)
P_E	$0 \leq P_E \leq$ Rated Maximum Power (by A7)

Rated Maximum Power is measured by manufacturers which shows the maximum power the solar panel can generate.

5 Requirements

This section provides the functional requirements, the business tasks that the software is expected to complete, and the nonfunctional requirements, the qualities that the software is expected to exhibit.

5.1 Functional Requirements

R1: Input the values requested by the system, which is the latitude of the solar panel, the date starts the calculation and the ending date.

R2: Output the valid values for the problem defined by $ProblemDescription$, which is the optimum tilt angle for solar panel, the predicted solar energy output.

R3: Determine the tilt angle by using $GD1$ and the solar energy output by using $IM3$

R4: Verify the output by using the Table: $OutputVariables$

R5: Reading the section of $Assumptions$ to know the related requirements regarding the outputs.

5.2 Nonfunctional Requirements

This section provides the non-functional requirements, the qualities that the software is expected to exhibit.

Correct: The outputs of the code have the properties described in Section: Properties of a Correct Solution

Verifiable: The code is tested with complete verification and validationplan

Understandable: The interface of this software shoulf support users to get the result within five stepts, and the output result should easily understand by the users.

Reusable: The code is modularized

Maintainable: The traceability between requirements, assumptions, theoretical models, general definitions, data definitions, instance models, likely changes, unlikely changes, and modules is completely recorded in traceability matrices in the SRS and module guide

Portable: The code is able to be run in different environments

6 Likely Changes

LC1: The system currently using the latest data of the solar's intensity, the calculation can be modified if this data upgrade in the future.$A3$

LC2: The system currently usingthe latest data of the solar panel's efficiency, the calculation can be modifiedif this data upgrade in the future.$A4$

LC3: The system currently using the latest data of the Performance Ratio, the calculation can be modified if this data upgrade in the future.$A5$

7 Unlikely Changes

LC4: The goal of the system is to predict the optimum tilt energy without considering the individual environmental difference from each case.A1

8 Traceability Matrices and Graphs

The purpose of the traceability matrices is to provide easy references on what has to be additionally modified if a certain component is changed. Every time acomponent is changed, the items in the column of that component that are markedwith an "X" may have to be modified as well. Table 4 shows thedependencies of theoretical models, general definitions, data definitions, and instance models with each other. Table 5 shows the dependencies of instance models, requirements, and data constraints on each other. Table 6 shows the dependencies of theoretical models, general definitions, data definitions, instance models, and likely changes on the assumptions.

	T1	DD2	DD1	DD3	GD1	IM1	IM3
T1							
DD2			X				
DD1				X			
DD3							
GD1	X	X					
IM1					X		
IM3						X	

Table 4: Traceability Matrix Showing the Connections Between Items of Different Sections

	IM1	IM3	4.2.6	R1	R2	R3	R4	R5
IM1			X	X		X	X	X
IM3	X					X	X	X
R1	X		X		X			
R2	X	X						
R3	X	X						
R4	X	X						
R5	X	X			X			

Table 5: Traceability Matrix Showing the Connections Between Requirements and Instance Models

	A1	A2	A3	A4	A5	A6	A7
T1							
DD2			X				
DD1			X				
DD3							
GD1	X	X	X				
IM1		X				X	
IM3	X			X	X	X	X
LC1		X					
LC2				X			
LC3					X		
LC4	X						

Table 6: Traceability Matrix Showing the Connections Between Assumptions and Other Items

The purpose of the traceability graphs is also to provide easy references on what has to be additionally modified if a certain component is changed. The arrows in the graphs represent dependencies. The component at the tail of an arrow is depended on by the component at the head of that arrow. Therefore, if acomponent is changed, the components that it points to should also be changed. Figure 3 shows the dependencies of theoretical models, general definitions, data definitions, instance models, likely changes, and assumptions on each other. Figure **??** shows the dependencies of instance models, requirements, and data constraints on each other.

9 Values of Auxiliary Constants

This section contains the standard values that are used for calculations in SC.

Symbol	**Description**	**Value**	**Unit**
I_S	Solar insensity	1.35	$\frac{\mathrm{kW}}{m^2}$
P_r	Solar insensity	18.7	%
PR	Solar insensity	0.75	%

References

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