

Simulation of Solar Parabolic Dish System using Graphical User Interface

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Abstract

Sunlight, a free and ecologically friendly renewable energy source that never runs out, is produced by the Sun. A whole year's worth of energy needs may be met by the hourly quantity of solar energy that enters the globe. It does not harm the environment and is thus quite effective. The conventional method of generating electricity has inherent disadvantages, including high carbon emissions and a dependency on fossil fuels. Renewable energy is converted into clean, reliable power. Despite the challenges associated with photovoltaic panels, other approaches to circumvent some of these limitations may be found in solar energy technologies like parabolic dish systems. Parabolic dish systems, particularly in hot climates like Malaysia, concentrate sunlight into a small area for improved efficiency and power output. This project presents the creation of a graphical user interface (GUI) for simulating any Solar Parabolic Dish parameters. The formulas are written as codes that can compute and simulate outcomes similarly to a manual approach. Moreover, MATLAB App Designer has been used and functions well. Using MATLAB App Designer, a graphical user interface (GUI) for a solar parabolic dish system is designed in the Johor Bahru location. GUI capable of simulating a 1kW parabolic dish system. Test and validation are done on the simulation of each specification under two different parabolic dish diameters.

1. Introduction

The increasing fear about the effects of climate change and the rise in the frequency of natural catastrophes make it crucial for there to be a significant shift in how energy is used worldwide. There seemed to be many ways to stop climate change from harming the ecosystem. The Sun generates solar energy through Sunlight is a free and environmentally beneficial renewable energy source that doesn't run out. In the modern period, we require electricity constantly. This solar energy is produced for use in commercial, industrial, and residential settings. It is simple to collect energy from direct sunshine. As a result, it is incredibly effective and does not pollute the environment [1]. This energy is the transformation of sun rays into power, either in a direct way using photovoltaic (PV) or in a roundabout way utilizing concentrated energy or concentrated solar PV [2]. The sun radiation is concentrated towards the heat receiver at the focal point of the dish collector using parabolic-dish solar concentrators, which are two-axis solar tracking systems. In parabolic dish systems, the sun's rays are focused onto a receiver using mirrors positioned above a parabolic-shaped dish.

2. Methods

The parameters used to create the concentrator for the 1kW PD System are identified in this section.

2.1 Diameter of the PD Concentrator

Knowing the concentrator's size or diameter is of the utmost importance before building the PD system. This is since the Stirling engine determines the size of the PD concentrator (2).

2.2 Sizing the Aperture area of concentrator

The concentrator's aperture area is where solar energy is absorbed. The quantity of thermal energy delivered to the receiver, the optical efficiency, and the concentration ratio of the PD system will all be impacted by the size of the aperture area for the concentrator. The quantity of thermal energy sent to the receiver will rise as the concentrator's aperture area increases (2). As a result, the concentrator's aperture area may be computed using:

$$Aperture = \frac{\pi}{4} D_{con}^2 \quad (2.1)$$

where,

D_{CON} = Diameter of concentrator

2.3 Focal Length of PD

Solar radiation is concentrated into the receiver using a parabolic mirror concentrator before reflecting and focusing on a focal point. However, it will necessitate constant modification to guarantee that the radiation will always be reflected at the focus point (2). An equation is often used to determine the focal length or the separation between the focus point and the concentrator:

$$Rim\ angle(\varnothing_{rim}) = (\pi/18) \times \theta \quad (2.2)$$

$$\frac{f}{D_{con}} = \frac{1}{4 \tan(\varnothing_{rim}/2)} \quad (2.3)$$

where,

\varnothing_{rim} = Rim angle

θ = Angle between Concentrator and focal point

f = focal length

D_{CON} = Diameter of concentrator

2.4 Focal Point Diameter

When solar energy is reflected at the focal point of a perfect concentrator, a circular image with a diameter of d will develop in a PD concentrator (see Equation. 2.3). As a result, mathematical formulae may be used to compute the focus point diameter (2).

$$d = \frac{f \times \theta}{\cos \varnothing_{rim} (1 + \cos \varnothing_{rim})} \quad (2.4)$$

where,

d = focal diameter

f = focal length

\varnothing_{rim} = Rim angle

θ = Angle between Concentrator and focal point

2.5 Sizing the Aperture area of Receiver

The key function of a receiver is to efficiently transport heat from the sun's reflected energy to the working fluid while absorbing the most amount of solar energy feasible. As a result, the receiver's aperture must be made big enough to allow for the transmission of a sizable portion of the concentrator's reflected solar energy onto the receiver. When aperture size increases, the amount of solar radiation is blocked increases. As a result, mathematical equations may be used to compute the receiver's aperture area (2):

$$Ar = \frac{\pi}{4} d^2 \quad (2.5)$$

where,

Ar=Aperture area of receiver
d=focal diameter

2.6 Geometric Concentration Area

The concentrator aperture area to the receiver aperture area ratio is known as the concentration ratio and is represented as follows (2):

$$C = \frac{Aperture}{Ar} \tag{2.6}$$

where,

C=Geometric Concentration Area
Aperture=Aperture Area of Concentrator
Ar=Aperture area of receiver

2.7 Efficiency of PD Concentrator

The amount of solar radiation that is reflected to the receiver at the concentrator's opening area is the main indicator of concentrator efficiency. As a result, the following equation may be used to compute the concentrator efficiency (2):

$$\eta_{conc} = E(\cos\theta_i\rho\emptyset) \tag{2.7}$$

where,

η_{conc} = Efficiency of concentrator
E=Aperture Area
 ρ = Mirror reflectivity
 \emptyset = Intercept factor

2.7.1 List of Materials and Reflectivity

Efficiency does also depend on materials that are used as a layer of concentrator to absorb sunlight. Table 1 below shows the materials and reflectivity.

Table 1 List of Materials and reflectivity

Material	Reflectivity (%)
Stainless Sheet	67
Iron Sheet	87
Aluminum	92
Silver	96

2.8 Power of PD

Equation (2.8) is an alternate formula to evaluate efficiency of photovoltaic panel (4). This formula is also used to calculate the power of solar parabolic dish and photovoltaic panel. Once the equation (2.8) is converted to equation (2.9) the formula is ready to use to evaluate power of solar parabolic dish.

$$Efficiency = \frac{Power \times 100\%}{Aperture \times G} \tag{2.8}$$

$$Power = \frac{Efficiency \times Aperture \times G}{100\%} \tag{2.9}$$

where,

Aperture = Aperture area of concentrator
G = Solar Irradiance (W/m²)

2.8.1 Solar Irradiance Chart

Fig.1 shows the Solar Radiation bar chart of every hour on January 1st, 2024. The chart below also shows the highest till the lowest solar irradiance according to every hour of the day.

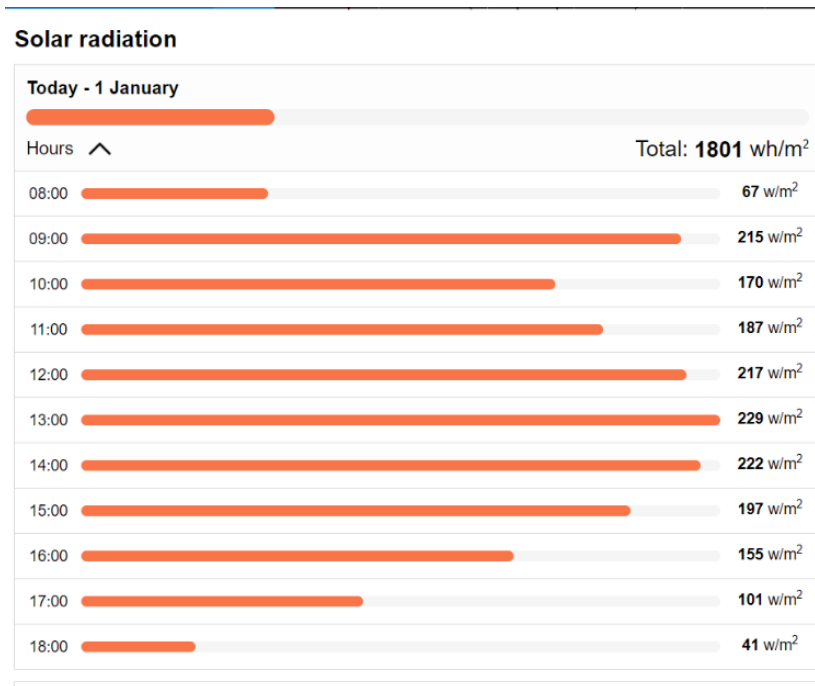


Fig. 1 Solar Radiation Chart on 1st January (5)

2.9 Graphical User Interface

In the MATLAB application, MATLAB App Designer is used to build and develop the GUI for this project. This helps to acquire the expected specification value of Solar Parabolic Dish system. The application includes a Main Menu and Calculation Tabs.

2.9.1 MATLAB App Designer

Without needing to be an expert software developer, MATLAB App Designer enables anyone to design complex apps. To build your graphical user interface (GUI), just drag and drop visual components; then, utilize the integrated editor to swiftly program its behavior (3). The project's GUI development workflow is depicted in Figure 2. The app designer code command window, which comprises of a component browser and a component library, opens first. Both parts serve as tools for designing and adjusting to user preferences. There are further sections of the command window titled "Design View" and "Code View," which display the project's design and code and operate in conjunction, respectively. We may create a project using Design View according to user preferences. Every instruction's code is inserted as a callback under CodeView. Upon successful execution of the code, an output tab appears. In addition to being an edit field, the tab performs computations using code under the Code View callback.

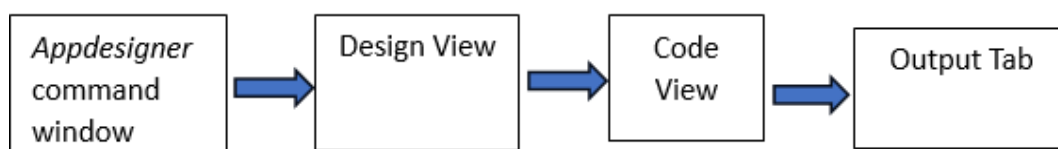
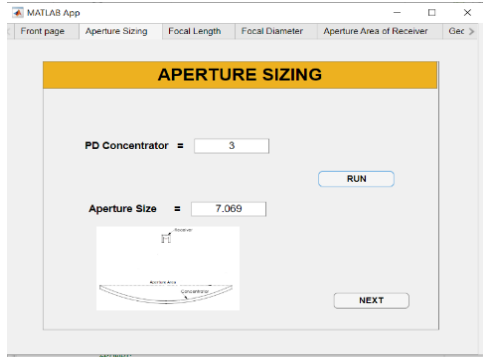
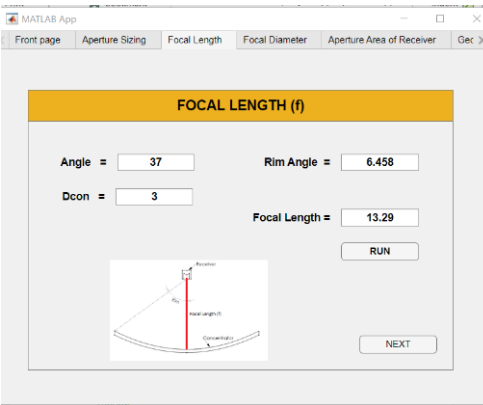
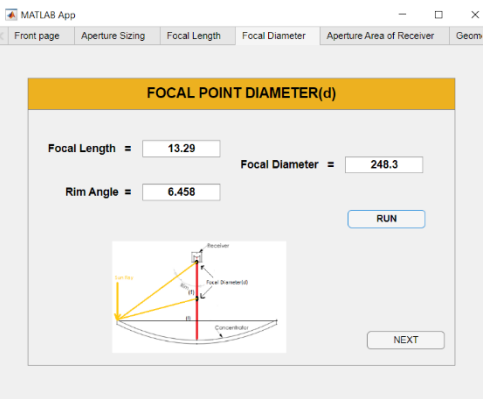
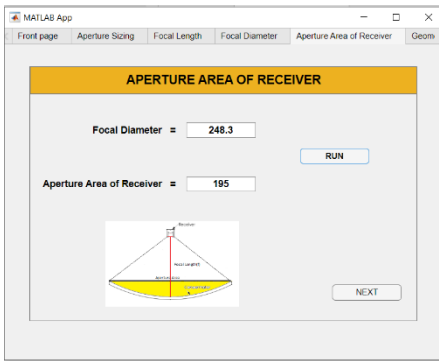


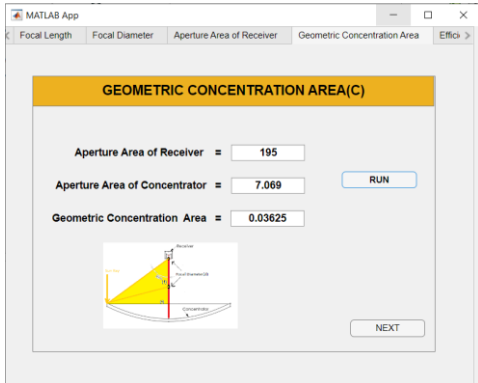
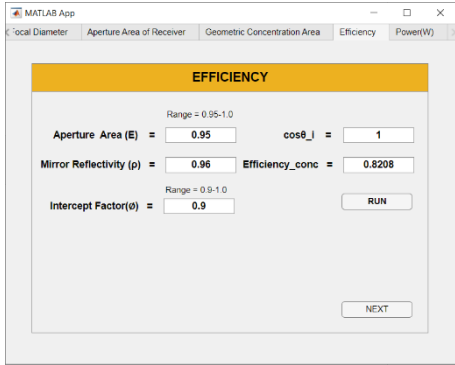
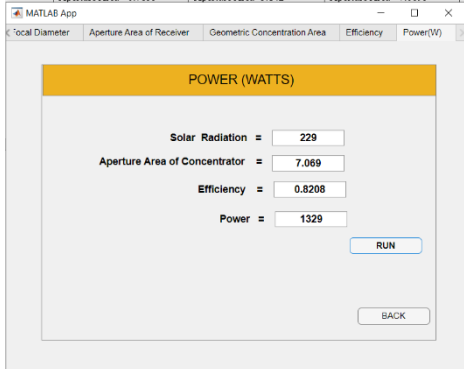
Figure 2 MATLAB App Designer Block Diagram

3. Results

The desired results and a description solar parabolic dish system are presented in this chapter. Results of development of GUI for solar parabolic dish simulation system are shown using two different parabolic diameters to prove that users can get result as per users desired. In this chapter, it also shows that power of 1kW of Solar Parabolic Dish is achievable solving through GUI that is build. Table 2 below shows the simulation results of diameter concentrator (Dcon) of 3 meter obtain from the GUI developed to design a solar parabolic dish of 1kW.

Table 2 Results of each parameter of solar parabolic dish using GUI

Parameters	Output
Aperture area of concentrator (m^2)	 <p>The screenshot shows the 'APERTURE SIZING' window of a MATLAB App. It features a navigation bar with 'Front page', 'Aperture Sizing', 'Focal Length', 'Focal Diameter', 'Aperture Area of Receiver', and 'Geom'. The main area has a yellow header 'APERTURE SIZING'. Below it, 'PD Concentrator' is set to 3, and 'Aperture Size' is calculated as 7.069. A diagram of a parabolic dish is shown with labels for 'Receiver', 'Focal Length', 'Concentrator', and 'Aperture Area'. 'RUN' and 'NEXT' buttons are present.</p>
Focal Length (f)	 <p>The screenshot shows the 'FOCAL LENGTH (f)' window. It has a yellow header 'FOCAL LENGTH (f)'. Inputs include 'Angle' = 37, 'Rim Angle' = 6.458, and 'Dcon' = 3. The calculated 'Focal Length' is 13.29. A diagram shows the dish geometry with labels for 'Receiver', 'Focal Length', 'Concentrator', and 'Aperture Area'. 'RUN' and 'NEXT' buttons are visible.</p>
Focal Diameter (d)	 <p>The screenshot shows the 'FOCAL POINT DIAMETER(d)' window. It has a yellow header 'FOCAL POINT DIAMETER(d)'. Inputs include 'Focal Length' = 13.29 and 'Rim Angle' = 6.458. The calculated 'Focal Diameter' is 248.3. A diagram shows the dish with labels for 'Receiver', 'Focal Length', 'Focal Diameter(d)', 'Concentrator', and 'Aperture Area'. 'RUN' and 'NEXT' buttons are present.</p>
Aperture area of Receiver (A_r)	 <p>The screenshot shows the 'APERTURE AREA OF RECEIVER' window. It has a yellow header 'APERTURE AREA OF RECEIVER'. Inputs include 'Focal Diameter' = 248.3. The calculated 'Aperture Area of Receiver' is 195. A diagram shows the dish with labels for 'Receiver', 'Focal Length', 'Focal Diameter', 'Concentrator', and 'Aperture Area'. 'RUN' and 'NEXT' buttons are visible.</p>

<p>Geometric Concentration Area (C)</p>	
<p>Efficiency of PD concentrator (η_{conc})</p>	
<p>Power (W)</p>	

4. Conclusion

The project's primary goal, to use MATLAB App Designer to simulate a Solar Parabolic dish GUI system in a Malaysian setting, has been accomplished. As mentioned in Section 2.8.1, the GUI system is especially meant to operate in Batu Pahat settings, however it is modelled on the conditions of the Johor Bahru area. Overall, the project objective was to create a graphical user interface (GUI) that could be used to simulate a parabolic dish system up to 1kW, as demonstrated in Section 4.2.8. It demonstrates that a 3-meter Parabolic dish diameter (DCON) produces power that is closest to 1 kW. Since the simulation of each specification under two distinct parabolic dish diameters is verified and confirmed. In conclusion, developing a GUI for simulation of each parameter of Solar Parabolic Dish has been presented in this project. The equations are formed as coding which can simulate and compute results like manual method. Furthermore, MATLAB App Designer has been implemented and worked effectively.

Acknowledgement

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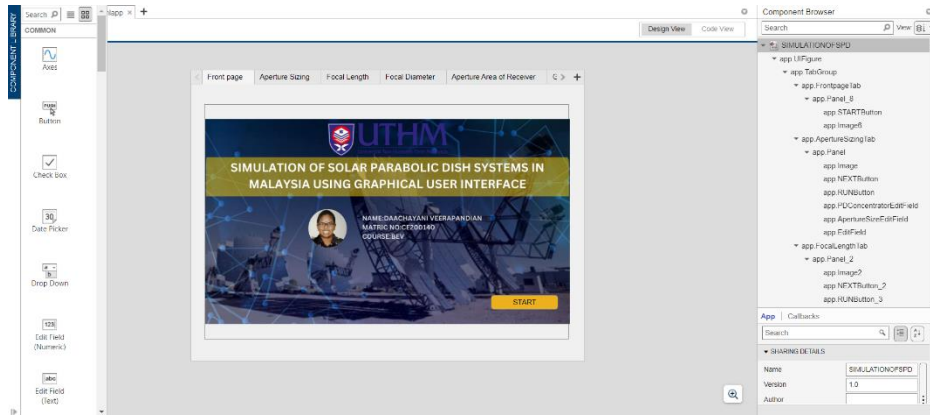
Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

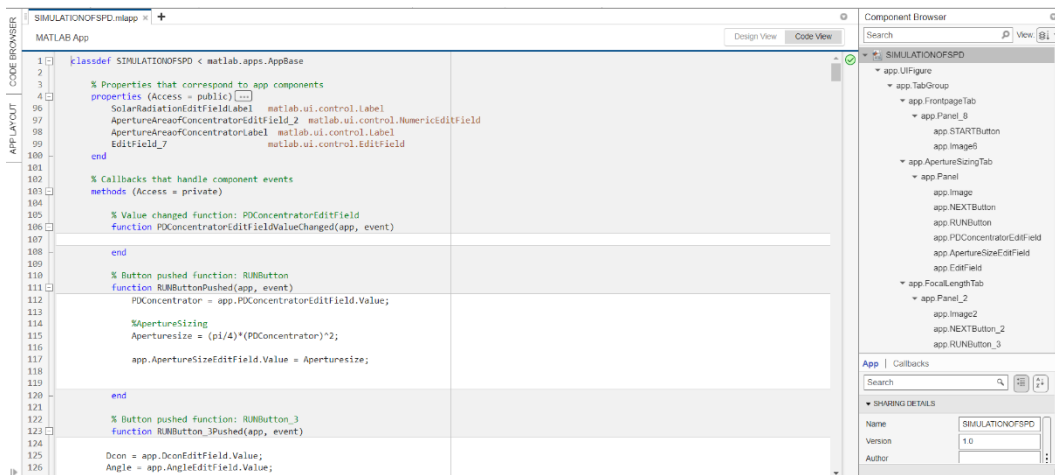
Author Contribution

The authors attest to having sole responsibility for the following: planning and designing the study, data collection, analysis and interpretation of the outcomes, and paper writing.

Appendix A: Design View of App Designer Command Window



Appendix B: Code View of App Designer Command Window



References

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