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Analysing Photovoltaic Carport Canopies Power Generation using Artificial Neural Network and Graphical User Interface

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Abstract: This study discusses Analyzing Photovoltaic Carport Canopies Power Generation Using Artificial Neural Network. Carports are free-standing buildings having a roof and solar canopies are an increasingly popular way to take benefits of parking and invest in solar power. Many factors could influence the power output of carport canopies such as depends on peak sun hours, temperature, and shading. Therefore, it is important to predict the PV system's optimal power output. This study will analyze the potential of Artificial Neural Network (ANN) with Graphical User Interface (GUI) which will be applied in the system of prediction of power output from photovoltaic (PV) panel system. To be verified efficiency and reliability, the proposed ANN model and GUI experimental output are in comparison with proposed mathematical equations. The novelty of this project is Renewable energy (RE) friendly, predicting solar panel power output and prediction of solar radiation for solar systems by ANN. Therefore, the prediction of solar power generation involving the calculations of parameters such as the weather, sun hours and temperature plays an important role as the solar panel output will not produce according to its rating. The results stated that the total number of PV panels for carport canopies is 1332. A large proportion of the designated car parking areas have been installed with carport canopies are currently about 11 rows of car parking areas. Also, total energy production for one year, which is 438370030.4 kWh. The total assured power output, maximum power output and net array for one year, values are 149178672 kW, 105096892.9 kW and 94587203.3 kW. The design of a GUI and an ANN which can predict solar power output on a daily, monthly, and annually has been successfully designed and developed.

Keywords: Photovoltaic, Renewable Energy, GUI, ANN

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1. Introduction

The method for producing electrical energy by transforming solar radiation into direct electricity through solar cells is termed photovoltaic (PV). Solar cells can generate direct energy from sunlight that can be used for power supply PV has been used to generate electricity for various purposes including electricity for satellites and spacecraft in outer space, as well as generating electricity for buildings on the face of the earth [1].

Photovoltaic provide 100% clean and renewable energy, which will allow being less dependent on fossil fuels, reducing CO2 emissions and preventing global warming [2]. Therefore, grid-connected PV represents one proper option to contribute to the mix of future energy sources in Malaysia [3]. Carports are free-standing buildings having a roof and solar canopies are an increasingly popular way to take benefits of parking and invest in solar power [4]. Car parks are truly a natural place for photovoltaic cells, where they can be installed as carports and generate free electricity and an additional profit with a solar carport [5]. And also, with a solar canopy, you can help to reduce the number of greenhouse emissions [6].

A solar parking canopy provides shade for cars and generates clean, sustainable energy for the Faculty of Electrical & Electronic Engineering (FKEE) QA Parking area. The advantage of the carport is that it helps the installers to orient the panels at the most appropriate angle of exposure to sunlight [7]. PV Carports, have photovoltaic panels on top of their surface, so that can capture solar energy and transform it into electrical energy [8]. Besides, the power consumption of the PV power system is predicted to increase [9].

1.1 Problem Statement

The photovoltaic solar cells with atmospheric output processing varies in many factors. Since sunlight is intermittent, solar cells are unable to generate electricity at a constant rate and the energy supplied at a particular time is therefore very much a function of weather factors. Solar radiation, temperature, relative humidity and wind speed are among other factors that affect the output performance of the photovoltaic solar system. PV system will not produce solar power generation value according to its rating due to the parameters of weather, sun hours and the temperature in Malaysia is averagely above 30 degrees Celsius. In addition, the estimation of solar power generation requires so much data on temperature, climate, and many more for a whole year [10].

The solar panel will only produce the rated output under its Standard Test Condition (STC). STC includes the solar panel temperature to be 25 degrees Celsius and the solar radiation of 1000 watt per meter square. Many factors could influence the power output of carport canopies such as depends on peak sun hours, temperature, and shading. The facts of the climate condition also distress the performance of PV panel output itself due to changing climate condition. These shading effects are static as well, as a result of the position of the shadow cast by moving clouds [11].

Besides that, data collection is also a problem to be discussed. The numbers of data collected, and its calculation will be more since its observation and data collection will be done every day which bring up the numbers of 360 above if it is done for one year. It will hard to summarize and analyze the data. Various numbers of data and complex calculation can also cause parallax error, where the error can occur during data collection on the side or and during analyzing the data by completing its calculation. An artificial neural network (ANN) system will be designed using this software and it perform calculations of the solar power generation. Also, Graphical User Interface (GUI) is designed to perform both calculations of the solar power generation and ANN system Thus, a prediction or forecasting tool is suitable to be used to generate these data [12].

The land used to place solar panel is called the solar farm. To build a solar farm large amount of land. Various types of land will be used for this solar farm [13]. The land could be mining land, agricultural land, industrial land or also private land. The land will have their profitability as there are effects from the side of the environment [14]. Build up solar panels as solar farm take up a lot of spaces if it covers up larger space on land then no agriculture works or construction works or any other works can be done. One of the benefits of a carport solar canopy is that the PV can produce electricity without affecting the function of the area as a parking space.

1.2 Objective

a) To design PV Carport Canopy for block QA Parking area.
b) To analyze the power output from PV Carport Canopies in QA Parking area.
c) To develop GUI and ANN that can be compared between computational method.

2. Materials and Methods

The Graphical User Interface (GUI) as made by using MATLAB Software which is app designer. The research in this paper focuses on developing a Graphical User Interface (GUI) and artificial Neural Network based application for predicting the electrical output of the PV array.

2.1 Equations

The most common procedure to determine the cell temperature consists of using the rule of the thumb. Tc based only on the passive behavior of the PV, not taking into account at the same time the actual weather. Secondly, predicting the electrical output of a PV panel is to calculate the PV assured power output. Thirdly, after the PVAP has been determined, the next step is to predict PV output by considering the temperature value. This is due to the fact of the PV panel will only be able to generate the rated power of 250C under the STC. After that, wiring and mismatch losses and soiling derating factor are related in calculating the net array power output. The soiling derating factor is taken into account as it is the accumulation of dust or dirt on the surface of the solar panels which is 0.9. In the fifth step, assuming Inverter's efficiency which is 0.9 implemented in calculating the maximum PV arrays. Finally, daily energy production as in Equation (2.6) is to predict the carport canopies photovoltaic power generation. This computational calculation is based on predicting the output of 1 PV panel with surrounding temperature. The everyday energy creation is determined day by day from January 2020 to December 2020.

a) 1. Tc = surrounding temperature + 20 degrees
b) 2. PVAP = PVrated × G × QPV
c) 3. PVout = PVAP + [PVAP × (t - 250C) + tco]
d) 4. PVarray = (PVout x wl x sdf)
e) 5. Max PVarray = PVarray x Ef
f) 6. Daily DEP = Max PVarray x PSH

2.2 Materials

The materials of this project are taken from real meteorological data which are obtained from RETScreen software and the AccuWeather website in Figure 1.

Figure 1: RETScreen Software and AccuWeather website

2.3 Graphical user interface

App Designer is an interactive development environment for designing an app layout and programming its actions. It gives a fully integrated model of the MATLAB Editor and a massive set of interactive UI components. Moreover, The GUI on this studies is designed and developed using

MATLAB App Designer. The software includes Main Menu and Calculation Tabs to gain the predicted value of PV power generation. Figure 2, 3, 4 and 5 show the designed layout for this app.

Figure 2: Main menu of GUI

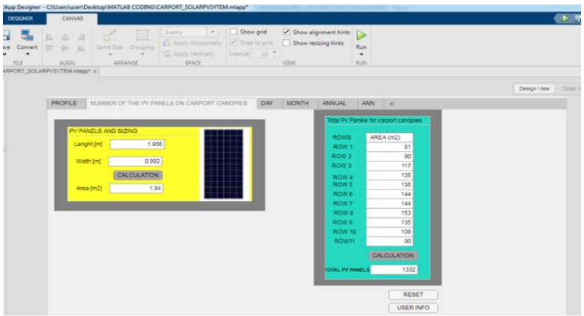

Figure 3: Number of PV panels on carport canopies

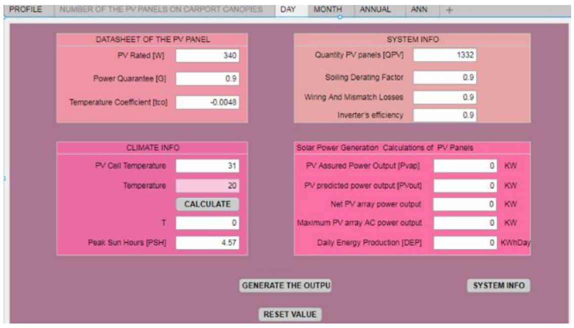

Figure 4: Prediction of carport canopies PV power generation for one day

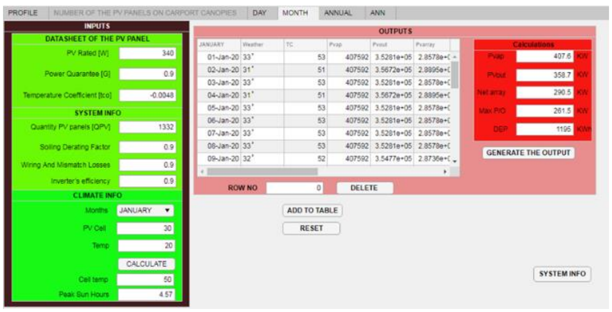

Figure 5: Prediction of carport PV power generation for one month

2.4 Artificial Neural Network

The ANN is applied whereby it reads the Annual data records collected on these studies. After that, when clicking the ANN Button, it starts generating all related ANN outputs and results will be displayed. In this study, ANN will be used to predict the values of PV array generation output. To accomplish this, the ANN configuration must be trained that ANN, can examine the connection between the given input quantities and the target values. Figure 6 shows that ANN window.

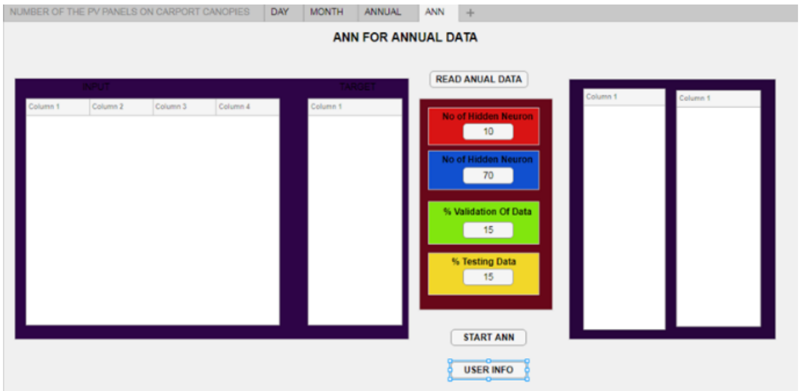

Figure 6: ANN window

3. Results and Discussion

3.1 Results

The overall energy production from January of 2020 to December of 2020 are calculated from excel calculation. Table 1 shows the total energy production for one year, which is 438370030.4 kWh. Moreover, for the total assured power output, maximum power output and net array for one year, the values are 149178672 kW, 105096892.9 kW and 94587203.3 kW shown in Table 2. The comparison of results for data collection and GUI are stated in the next part.

Table 1: Total energy production for one year

Month	Total Energy Production (kWh)
January	36587391.67
February	38732579.64
March	40026736.18
April	37417119.74
May	36689796.12
June	35457614.73
July	36100604.42
August	35914298.67
September	36131373.3
October	37307455.7
November	34080374.61
December	33924685.61
Total	438370030.4

Table 2: Total PVap, Max ACout and Ner Array for one year

Month	PVap (kW)	Net Array (kW)	Max ACout (kW)
January	12635352	8895548.667	8005993.8
February	11820168	8308146.641	7477331.9
March	12635352	8824236.371	7941812.7
April	12227760	8536874.228	7683186.8
May	12635352	8862269.595	7976042.6
June	12227760	8620864.266	7758777.8

July	12635352	8933581.892	8040223.7
August	12635352	8927243.021	8034518.7
September	12227760	8633542.008	7770187.8
October	12635352	8914565.279	8023108.7
November	12227760	8665236.362	7798712.7
December	12635352	8974784.552	8077306.1
TOTAL	149178672	105096892.9	94587203.3

3.2 Design of ANN

This ANN is applied to read the data collection and predict the values of PV array power generation output. ANN tab for annual data in which required values are entered which is the number of hidden neurons, percentage of training data, validation data and testing data. The input values are set to the ANN configuration which is cell temperature, PV panel rating, number of PV panel and PSH values while the ANN output is daily energy production. Figure 7 shows that ANN for annual data tab.

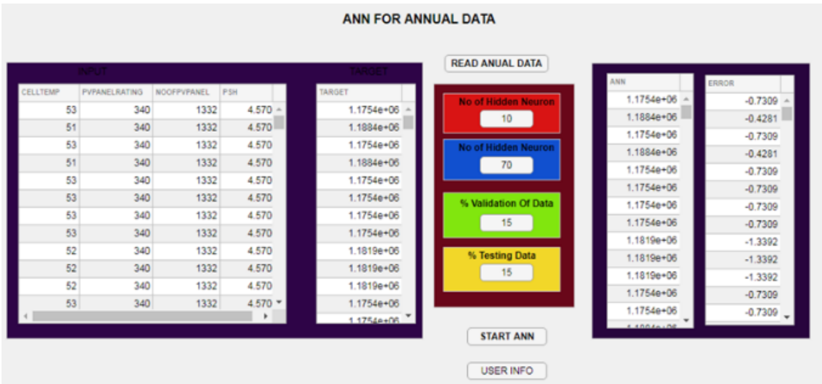

Figure 7: ANN for annual data

The total energy production of a PV array predicted by the improved ANN model. To improve the analysis process easier, the prediction of all values are obtained in Figure 8. Table 3 shows that the improved ANN model can predict the total energy production of a PV array that is close to the targeted parameters. The highest error is on Jan 2020 which is 0.00000069, while the lowest error is recorded on Dec 2020. According to Table 3, the improved ANN model accurately and predict the total energy production of a PV array which is similar to the target values.

It can be observed from Figure 8 that the Bar graph of total energy production is predicted by ANN model. ANN model can predict the PV array total energy production close to the target values. Moreover, the difference values between the target and ANN prediction values are approaching zero value. The highest prediction recorded is only 40026709.04 in March.

Table 3: Total energy production predicted by the development ANN model

Month	**Calculations (target)**	**Ann Prediction**	**Error**
January	36587391.67	36587417.24	0.00000069
February	38732579.64	38732571.11	0.00000022
March	40026736.18	40026709.04	0.00000068
April	37417119.74	37417128.27	0.00000023
May	36689796.12	36689795.49	0.00000018
June	35457614.73	35457610.38	0.00000012

July	36100604.42	36100602.72	0.00000005
August	35914298.67	35914289.17	0.00000026
September	36131373.3	36131363.98	0.00000025
October	37307455.7	37307446.62	0.00000024
November	34080374.61	34080376.16	0.00000005
December	33924685.61	33924683.28	0.00000007

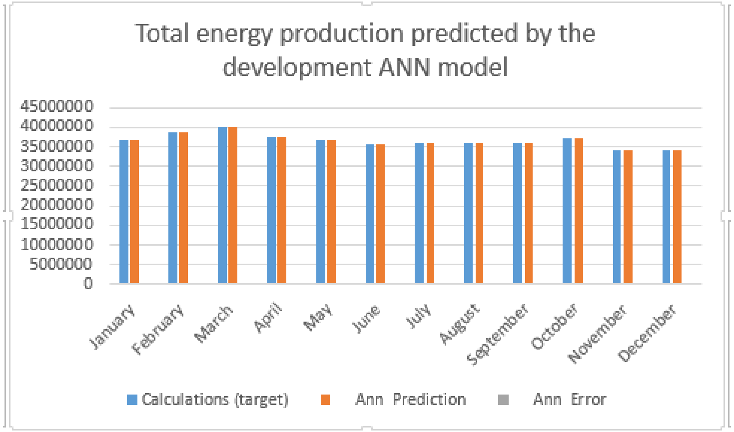

Figure 8: Bar graph of total energy production predicted by ANN model

4. Conclusion

Throughout this project, data collection of data and PV array design on the carport canopies of FKEE Block QA has been discussed in this study. The collection of data is based on meteorological data from the software of RETScreen and the online website called AccuWeather. The objectives for this project has been achieved project which is to design a PV canopy for block QA Parking area by Sketchup software, to analyze the power output from PV Carport Canopies in QA Parking area and develop GUI and ANN that can be used for analyzing PV Carport Canopy. Lastly, the GUI and ANN have been successfully designed and developed in the software.

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