WIND LOADING ANALYSIS ON A RESIDENTIAL ROOF MOUNTED PHOTOVOLTAIC PANEL

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A report submitted
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DECLARATION

I declare that this project report entitled "Wind Loading Analysis on A Residential Roof Mounted Photovoltaic Panel" is the result of my own work except as cited in the references

Signature: ....

Name: ....

Date: ....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the Degree of Bachelor of Mechanical Engineering

Signature	: ....
Supervisor's Name	: ....
Date	: ....

DEDICATION

To my beloved father and mother for their understanding and support.

ABSTRACT

Solar is one of the renewable and alternative energy sources. Nowadays, solar PV is commonly installed at the rooftop of a residential house free of obstruction and highly efficient. There are a lot of factors need to be considered when installing the solar PV panel. One of the most important factors is the wind loading acting on the solar PV panel. Negligence to consider wind as potential risk can prove fatal to the structure of the rooftop and can even risk of injuring nearby people. This project was carried out to simulate the wind acting on the residential house's rooftop when installed with solar panels by varying the wind direction and tilt angle of panels. Through the wind flow field, pressure contour and pressure coefficients Cp result was predicted from simulation work. It was observed that the solar panel experienced lifting force that pulls the structure away from the rooftop and it became more obvious as the tilt angle increased from 20° to 30°. The same changes in pressure and wind flow field also occurred at different wind direction when increasing the panel tilt angle to 30°. The pressure acting on the panel is more varied in term of pressure contours and values especially at the bottom of the panel. The lifting force acted at bottom area of the panel increased as the tilt angle increased to 30°. Therefore, projected the influence of tilt angle and wind direction on wind loading on residential roof mounted solar photovoltaics panel. For future work, different type of roofs can be simulated to predict the geometrical influences to the wind loading on solar PV panels. The simulation work can be compared with experimental work for better result validation.

ABSTRAK

Tenaga solar adalah salah satu daripada sumber tenaga boleh diperbaharui. Masa kini, solar PV selalunya dipasang di atas bumbung rumah perumahan kerana bebas dari halangan dan bercekapan tinggi. Pelbagai faktor harus dipertimbangkan semasa pemasangan panel solar PV. Antara faktor yang penting ialah beban angin yang bertindak pada panel solar PV. Kecuaian untuk mempertimbangkan angin sebagai potensi risiko akan mendatangkan bahaya kepada struktur bumbung bahkan berisiko untuk mencederakan orang yang berdekatan. Projek ini dijalankan untuk mensimulasikan angin bertindak pada bumbung rumah perumahan apabila dipasang dengan panel solar dengan mempelbagaikan arah angin dan sudut kecondongan panel. Medan angin, kontur tekanan dan pekali tekanan, Cp telah diramalkan melalui kerja simulasi. Ia diperhatikan bahawa panel solar mengalami tenaga angkat yang menarik struktur dari bumbung dan ia menjadi semakin jelas semasa sudut kecondongan meningkat dari 20° ke 30°. Perubahan yang sama pada tekanan dan medan angin juga berlaku pada arah angin berbeza apabila sudut kecondongan panel ditingkatkan ke 30°. Tekanan yang bertindak pada panel lebih pelbagai dari segi kontur dan nilai tekanan terutamanya pada bawah panel. Daya angkat yang bertindak di bawah kawasan panel meningkat semasa sudut kecondongan meningkat kepada 30°. Justeru, menunjukkan pengaruh sudut kecondongan dan arah angin pada beban angin bertindak pada panel solar. Untuk kajian masa depan, bentuk bumbung yang berbeza boleh disimulasikan untuk menjangka pengaruh geometri pada beban angin. Kerja simulasi juga boleh dibandingkan dengan kerja eksperimen untuk pengesahan yang lebih baik.

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LIST OF SYMBOLS

m	meter
F	force
V	velocity
°	angle
°C	temperature (Celsius)
L	length
W	width
t	thickness
GW/h	power (10^9)
kW/h	power(10^3)
Cl	lift coefficient
Cd	drag coefficient
Cp	pressure coefficient
C_{PU}	pressure coefficient upper
C_{PL}	pressure coefficient bottom/lower
U_H	wind speed (m/s)
U_0	wind speed (m/s)
ρ	density
Po	free static stream pressure
P	pressure

LIST OF ABBREVIATIONS

RE	Renewable Energy
PV	Photovoltaic Panel
SEDA	Sustainable Energy Development Agency
CFD	Computational Fluid Dynamics
AC	Alternating current
DC	Direct current
WTT	Wind tunnel testing
WOW	Wall of Wind
RANS	Reynold Average Navier Stokes
SST	Shear Stress Transport
APA	American Psychological Association

CHAPTER 1

INTRODUCTION

1.1 Background

Renewable energy (RE) is one of the best alternatives to the conventional electrical generator. Since the discovery of electricity, human's life benefit greatly from it. Electricity power for an example can be produced in a power plant through multiple processes before being distributed to residential and industrial area. With the fast-growing electricity power consumption and the concern for the increasing greenhouse gas emission that caused climate change have started the sustainable policies development in regarding the renewable energy had been introduced. The renewable energy provided better and cleaner environment while providing humanities with electricity through greener method.

One of the types of renewable energy is solar energy. The irradiance from the sun is collected via solar panel or solar photovoltaics panel which can then be processed into electricity power. Malaysia is a country that relies on non-renewable resources such as fuel and gas to generate energy. Located on equator, Malaysia is blessed with temperature average ranging from 25°C to 40°C throughout the year. [32] Due to this, Malaysia is suitable to implement solar energy as one of its renewable energy.

Based on a report by Sustainable Energy Development Authority (SEDA), 2017 shows an increase of solar PV application by the year 2017. Solar PV panel hold 26.95% of the type of renewable energy being practiced in Malaysia with almost 9000 applications. This is due to faster installation and the price going much cheaper over the year. In term of energy generation, solar PV shows increment over the year by generating 330.03 GW/h compared to 272.44 GW/h in 2015.

When designing solar PV panel for installation, there are several parameters that need to be considered to achieve the best operating condition. The significant parameter is type of roof, tilt angle of the solar panel, dimension of solar panel, exposure hours, solar PV facing direction and dust accumulation [27]. In this study, the critical parameter that affect the wind loading on the photovoltaic panels has been investigated.

1.2 Problem Statement

There is a very important factor that need to be considered when designing solar panel system before installation is made to the buildings which is the wind loading force on solar photovoltaic panel. Improper design when installing is done can causes the improper pressure distribution on PV panel and structural damage to the system and even worse to the roof. At certain zones of the roof, there's a possibility of air pressure drop on top of the panel. The difference in pressure between below and above surface of the roof creates uplift forces that causes failure of panel and roof. Hence, the effect of tilt angle of the PV panel, PV panel geometrical scales, roof type, clearance height and wind direction are significant to investigate the flow distribution near the roof.

1.3 Objectives

1. To determine the parameter affecting the wind force impacted on the photovoltaic panel.
2. To obtain the wind flow field, pressure contour and pressure coefficients acting on the roof top.

1.4 Scopes

1. The simulation is to simulate the wind flow on PV panel roof mounted on low rise buildings (residential house) only.
2. The wind speed to use is the highest average wind speed 4.5 m/s in Malaysia.
3. The tilt angle is parallel, parallel + 10° to test the influence of tilt angle on wind loading on PV panel.

1.5 Methodology

The aim of the project is to simulate the wind passing through the PV array and find the wind loading acting on the PV arrays. Figure 1.1 shows the steps in carrying out the study

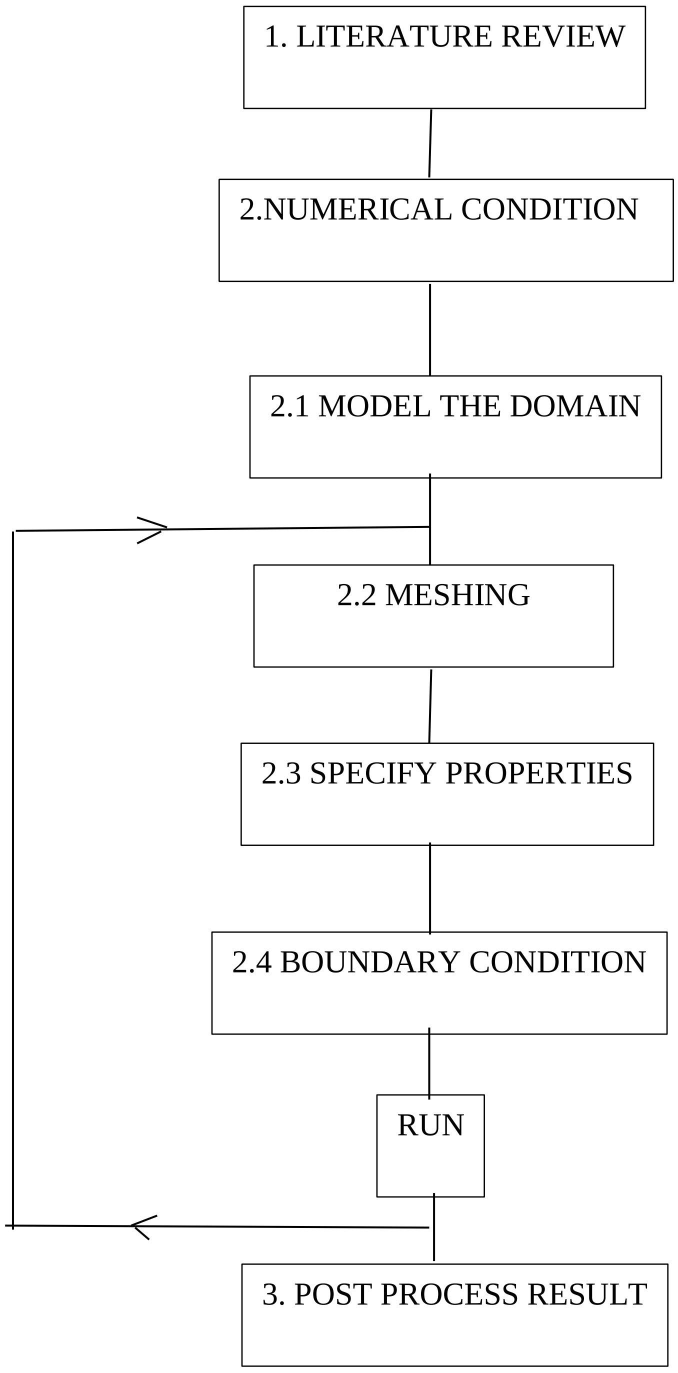

Figure 1.1 Flowchart of simulation steps

In order to understand the aim and concept of the simulation, multiple journal and research taken as references. From the journal, the wind loading on PV panel or arrays are critically influenced by the tilt angle of the panel and the wind direction acting on the panel. Others influences are presence such as the gap between the module however the effect is to be minimal and not significant [1]. The type of the roof also critical parameter. However, this simulation only will be focusing on simple gable roof.

For numerical modelling of the simulation, a 3D model is created. The model of house has the dimension of 6 m length x 21 m width with 2.1 m height to the roof. The roof dimension is to be 8 m length and 21 m width with a 20° pitch. The dimension of the individual solar panel is 0.814 m length x 1.6 m width x 0.04 m thickness. The array consisted of 5 modules in a row with size of 4 m length and 8 m width. The arrays are kept near the edge and centre of the roof. This is the standard gap left for installation and maintenance. The PV arrays are kept to parallel inclination while facing north and south. [27]. The inclination angle is chosen based on optimum power output at place with latitude of 4°.

The CFD simulation is performed for two different wind direction. A study of wind loading analysis on PV panel differs with types of roof and tilt angle is done by Naeiji, A. et. al [1]. The arrays of solar PV are mounted on hip roof. Models are subjected to different wind direction 0°, 90°, 180° and 270°. Based on result, wind force coefficient for hip roof are affected by the wind direction and tilt angle. The critical values are noted at 180° and 0° wind direction.

The computational domain is set at 70 m length x 105 width and 12 m height. At the domain inlet, the model is subjected to a constant wind speed at 4.5 m/s [31]. The wind speed is the highest wind speed at 10 m height of each month in Malaysia averaged from year 1993 to 2016.

In order to analyse fluid flows, the flow domain is split into smaller subdomains made up of hexahedra or tetrahedra in 3D. The governing equation is then solved inside each of the subdomains. Then, the next step is to set the flow inlets and flow outlets of the domain. The sides and top of computational domain are set as slip wall. A velocity inlet is used at the upwind boundary while a pressure outlet boundary is used at the downwind boundary. The bottom wall of the domain will be specified as no slip wall to simulate the effect of surface roughness.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The main focus of the project is to investigate the wind loading on roof mounted photovoltaic panel. The chapter analyses the wind loading on PV panel situated on the ground and above the roof and the parameter that affect the wind loading on the panel. The chapter begins with brief introduction of solar PV and the factors that affect the PV panels.

2.2 Solar Photovoltaic Panel

Photovoltaic panel as shown in Figure 2.1 is semi-conductor panel that convert irradiance from the sun rays to electricity. The panel is normally made from crystalline silicone. Differentiate with solar collector, the panel needs the amount of irradiance from the sun not the heat from the sun itself.

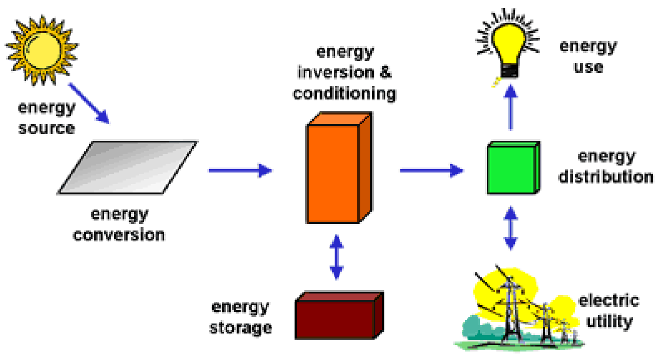

Figure 2.1: Basic PV operation (Source: Florida Solar Energy Center)

Solar panel works by allowing light to move electron from atom that can generate a flow of electricity. The electricity flow is then converted from AC to DC current by inverter before it is stored or used for electricity utility.