Potential Electricity Generation from Small Scale Solar Photovoltaic Systems -

Case Study 1: Solar Harvesting Potential from roofs of Invercargill Homes

And

Case Study 2: Model Validation using Existing Data from PV Generation on Selected New Zealand Schools

A thesis presented in partial fulfilment of the requirements for the degree of

MASTER OF CONSTRUCTION

School of Engineering and Advanced Technology

At Massey University, Albany,

New Zealand

SAMANANT SAKDISETH

2015

ABSTRACT

Solar energy is abundant, free and non-polluting. Solar energy can offset the consumption of fossil fuels, greenhouse gas emission reduction targets and contribute to meeting the fast-growing energy demands. The use of solar energy for electricity generation from photovoltaic (PV) panels has increased but is still not a widely utilised technology in New Zealand. This research approximated the potential solar energy that could be harvested from the rooftops of existing residential buildings in a case study city.

This research is divided into two work strands, each involving a case study. The first strand investigated if a model could be developed, using existing data sources to determine the solar harvesting potential from the rooftops of existing residential buildings. The second strand involved the validation of the solar PV prediction model proposed in the first strand of the research, to test the reliability of the modelling outcomes.

Invercargill City was selected as the study city for case study 1. Invercargill is the southernmost city in New Zealand so represents a worst case scenario. The method involved merging computer-simulation of solar energy produced from PV modelling and mapping incoming solar radiation data from north facing residential rooftop area. The work utilised New Zealand statistical census map of population and dwelling data, as well as digital aerial map to quantify the efficient roof surface area available for PV installations. The solar PV potential was calculated using existing formulas to investigate the contribution of roof area to the solar PV potential in buildings using roof area and population relationship.

The estimated solar PV potential was 82,947,315 kWh per year generated from the total solar efficient roof surface area of 740,504 m^2. This equates to approximately 60.8% of the residential electricity used in Invercargill's urban

area, based on the 7,700 kWh typical annual electricity consumptions per household. The result represents an immense opportunity to harvest sustainable energy from Invercargill's residential rooftops.

To verify the accuracy of the developed method for predicting the PV outputs, the model was applied to actual generation data from grid-connected solar photovoltaic (PV) systems that are installed in New Zealand schools under the Schoolgen programme (Case Study 2). A total of 66 Schoolgen PV rooftop models were incorporated in the analysis. At this stage, the actual system parameters including size, panel type and efficiency were included in the analysis. The performance prediction and analysis outcome showed the parameters and operating conditions that affect the amount of energy generated by the PV systems. This part of the research showed the area where the PV model can be improved.

The predicted generation from the model was found to be lower than the actual generation data. Schoolgen systems operating at over 0.75 performance ratio were found to be underestimated. This indicated that most Schoolgen PV systems were operating at higher capacities than predicted by the default value of system losses. The analysis demonstrated the effects of PV technology type, site orientation, direction and tilted angle of the panels on the ability to generate expected amount of potential capacity based on solar resource availability in different site scenarios. This in turn has provided more in depth analysis of the research and served to expand the area for improvements in the design of the model.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude and appreciation to my chief supervisor, Professor Robyn Phipps, for her constant advice and guidance, with generous support and encouragement from the beginning through to the completion of this thesis.

I would also like to thank my co-supervisor, Professor Jasper Mbachu, for the time and effort discussing research topics and direction.

I am grateful to the love and support of my family. Their patience and kind understanding have truly contributed in making this study possible.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATIONS

ABBREVIATIONS

AC: Alternating Current electricity

BIPV: Building Integrated Photovoltaics

BOS: Balance of System

CAD: Computer Aided Design

COP: Coefficient of Performance

DC: Direct Current electricity

DEM: Digital Elevation Model

DHI: Diffuse Horizontal Irradiance

DNI: Direct Normal Irradiance

FIT: Feed-in Tariff

GIS: Geographic Information System

GHI: Global Horizontal Irradiance

GW: Gigawatts (10^9 Watts)

GWh: Gigawatt-hour

HEEP: Household Energy End-use Project

kW: Kilowatt (10^3 Watts)

kWh: Kilowatt-hour

kWp: Kilowatt-peak

LCOE: Levelized cost of electricity

LiDAR: Light Detection and Ranging technology

MJ: Megajoule (10^7 Joules)

MPP: Maximum Power Point

MPPT: Maximum Power Point Tracking

MWh: Megawatt-hour (10^7 Watt-hours)

OECD: The Organisation for Economic Co-operation and Development

PV: Photovoltaics

PJ: Petajoule (10^{15} Joules)

RPS: Renewable Portfolio Standards

SVF: Sky View Factor

UHI: Urban heat island