UNIVERSITI TEKNOLOGI MARA

A HYBRID ANN FOR OUTPUT POWER PREDICTION AND ONLINE MONITORING IN GRID-CONNECTED PHOTOVOLTAIC SYSTEM

PUTERI NOR ASHIKIN BINTI MEGAT YUNUS

Thesis submitted in fulfilment
of the requirements for the degree of
(Electrical Engineering)

Faculty of Electrical Engineering

August 2023

ABSTRACT

This thesis presents a new algorithm for output prediction and online monitoring in a Grid-Connected Photovoltaic (GCPV) system based on an artificial neural network. Initially, Multi-Layer Feedforward Neural Network (MLFNN) models for the prediction of total AC power output from a grid-connected PV system have been considered. Three models were developed based on different sets of inputs. It utilizes solar irradiance (SI), ambient temperature (AT) and module temperature (MT) as its inputs. However, all three models utilize similar type output which is total AC output power (P_{AC}) produced from the grid-connected PV system. After that, a hybrid of MLFNN with other optimization methods was introduced, i.e. Improved Fast Evolutionary Programming (IFEP), Evolutionary Programming- Dolphin Echolocation Algorithm (EPDEA) and Evolutionary Programming-Firefly Algorithm (EPFA). The comparison between IFEP, EPDEA and EPFA was compared to determine which model performs better for single-objective optimization. The EPDEA model showed the best in terms of fitness solutions. The results showed that EPDEA scheme provides accurate prediction by producing the highest coefficient of determination, R^2 and the lowest Root Mean Square Error (RMSE). Lastly, the output power performance of a GCPV system progressively monitor at specific interval. The actual data of SI, MT, AT and P_{AC} from the server has been called and uploaded every five-minute interval into Matlab by using File Transfer Protocol (FTP) coding. At this stage, the hybrid EPDEA was selected to be used in the system as it was the best optimization in the hybridization method. All data were then compared to the predicted data that have been developed in the training process, leading to the identification of possible fault in the system. Any predicted AC output power less than the threshold set up, indicates an error has been occurred in the system. The obtained results show that the proposed technique can monitor system under-perform as fast as five minutes. Therefore, the proposed of the system for prediction and online monitoring are justified.

ACKNOWLEDGEMENT

Firstly, Alhamdulillah, this thesis is completed with His graciousness and blesses. I wish to express my sincere gratitude to my main supervisor, Associate Professor Ir. Ts. Dr. Shahril Irwan Sulaiman, for his great guidance, concern, motivation, enthusiasm, and immense knowledge towards completing my studies. My deepest gratitude and appreciation are expressed to my co-supervisor, Professor Dr. Ahmad Maliki Omar, for his valuable input, guidance and encouragement towards completing this study.

My supportive husband, Mohd Khairil Izani Ibrahim, my caring father,
and my beloved mother, , for the encouragement, emotional and technical support, and understanding throughout the years of my studies. To all my children, I am also indebted for sacrificing their prime development time for me to pursue my PhD, Khayla Nur Amna, Keisha Nur Aina, Khayra Nur Azraa, Kaseh Nur Alya and Kaisar Nuh Amsyar– may this be an inspiration to them for their pursuit of academic excellence. I am truly blessed to have all of you in my life.

I also wish to thank University Technology MARA (UiTM) and Ministry of Higher Education (MOHE) for giving me the opportunity and scholarship to pursue my PhD. May this modest work contribute to future studies and research. Last but not least, I would like to thank all individuals who have involved directly or indirectly in the successful completion of my study.

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

1.1 Research Background

The growth of renewable energy (RE) as an alternative energy source has been further enhanced to support the continuous increase in energy demand complemented with nominal efforts on energy efficiency (EE) measures. To ensure this success, the Malaysian Government has been created a paper work entitled Green Technology Master Plan Malaysia 2017-2030 [1] . This Master Plan is to facilitate the Transformasi Nasional 2050 (TN50) which is an initiative to position Malaysia amongst the top countries in the world in economic development, citizen well-being and innovation by the year 2050.

Besides, the goal of the Malaysian government is to installed capacity of 8885 MW for renewable energies (RE) by 2030 [2]. Malaysia aimed to generate 20% of the country's electricity from renewable sources by 2030. Examples of RE technology are wind power, geothermal energy, hydropower, biomass and photovoltaic. According to the Global Status Report REN 21 [3], solar photovoltaic (PV) has been one of the fastest growing renewable energy technologies for more than a decade. At the end of 2017, the total global PV capacity reached 303 GW. Most of this capacity was met by grid-connected photovoltaic (GCPV) systems.

A typical GCPV system is shown in Figure 1.1 and mainly consists of PV generators and inverters. A PV array consists of PV strings which connected in parallel, while each string consists of several PV modules that are connected in series. The smallest unit of a PV module is called a solar cell. These cells convert sunlight into direct current. The direct current from the PV array is then converted to alternating current using an inverter. In addition, the AC power supply is conditioned in such a way that the electrical properties are similar to the properties of the mains current. The alternating current from the inverter is later exported to the grid or consumed by the load demand.

The rapid growth of GCPV systems has been accelerated primarily due to improved competitiveness, increasing electricity needs, better awareness of the