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Application of Web Application Package and Adaptive Neuro Fuzzy Inference System in Photovoltaic Technology: A Review

Ahmad Wafi Taqiuddin, Aimi Rauqah Abdul Razak, Ahmad Fateh Mohamad Nor*

Green and Sustainable Energy Focus Group (GSEnergy), Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Malaysia.

*Email :afateh@uthm.edu.my

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Abstract:

Photovoltaic is the conversion of light into electricity using semiconducting materials that exhibit photovoltaic effect or sunlight. This paper aims to investigate the potential of a Web Application Package and Adaptive Neuro-Fuzzy Inference System (ANFIS) configuration in Photovoltaic (PV) System. The review in this paper shows that Web Application Package is designed to have the capability to sizing the load consumption and determine the usage of every component for the grid-connected PV system, including costing and total payback period. System sizing is vital to ensure all the equipment involves to not producing extra energy needed which related to the costing and total payback period.

Keywords **—Web Application Package, ANFIS, Photovoltaic Module, Renewable Energy.**

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I. INTRODUCTION

The needs for electricity keep expanding more and more in every aspect of our life. While the world encounter problem of insufficient of non-renewable energy such as coal and oil as main source of electricity, the growth of population keeps increasing [1]. With limited source for electricity and the demands keep rising, it was a necessity to look for new alternatives such as solar, hydropower and geothermal as renewable source. In addition, the usage of renewable energy can lessen the greenhouse gas (GHG) as well as preserve the environment making it become more useful at many region. There are many developing countries that already exploring renewable energy sources to gain benefits from it. For example, in South Korea, PV energy is spreading very quickly after the launch of Renewable Portfolio Standards (RPS) program [2].

Photovoltaic (PV) or solar energy will be using sunlight as main resource for generating electricity. It also is known as the most clean and abundant renewable energy that available. Photovoltaic system usually consists of a number of components such as cell that arranged on a module and few modules are strung together to create the system size that has been desired. Those cells will produce a small direct current and was directed to inverter to convert it into alternating current that will be used for home and industrial area.

Web Application Package are Google Sites with Integration of Calconic that may be accessed through a web browser. The designer be able to use Panel which has 3 tabs consist of insert, pages and themes where may easily and for free establish a website [3]. Google Sites is a simple tool for enhancing learning by combining Google Docs, Slides, Sheets, Forms, YouTube, and embed code from another application whereas in this project the embed code is implemented with the integration of Calconic. Calconic is an interactive calculator builder that allows users to create bespoke interactive calculators and integrate them into their websites [4]. Custom online calculators are used to attract, engage, and convert new website users who are looking for answers. In Google Sites, users can

compile a variety of content into a single location including the embed code including text, pictures etc.

Adaptive Neuro-Fuzzy Inference System (ANFIS) is an artificial intelligence system that integrates neural networks and fuzzy logic principles. The interference system also is complementary with a set of fuzzy that have capacity to generate non-linear functions making it to be acknowledge as universal estimator. Fuzzy neural networks are capable to estimate any kind of power plant with high precision even if it were related to engineering, transportation, business, and medicine. ANFIS generates by modulate all its adjustable parameters in order to obtain desired output with minimum error called as Root Mean Square Error (RMSE). This technique is outstandingly a potential tool but yet to be analyzed in various other non-linear and complex prediction of control problems [5]-[7].

II. WEB APPLICATION PACKAGE IN PV

The researchers in [8] have stated that solar energy is one of the natural energy sources that is regarded to be one of the most beneficial since it is free, plentiful, pollution-free, and the most extensively distributed, and the trend of solar energy application is the photovoltaic (PV) grid-connected generating system. They found that the inverter that is linked to the grid receives its input from the solar cell array, which transforms the solar energy that is derived from the light energy into dc electricity. Current control and voltage control are the two strategies for controlling the output of a photovoltaic generating system that is linked to the grid.

Next, the researchers in [9] have concluded that solar PV systems are extensively employed across the world to transition from fossil fuel-based power generation to clean and renewable energy production because they have the potential to reduce greenhouse gasses emissions. Greenhouse gases (GHSs), which are produced when conventional power plants burn fossil fuels, are the primary cause of climate change. These gases are emitted by conventional power plants. Gases such as carbon dioxide (CO2), methane, nitrous oxide, water vapor, and others are included in the category of greenhouse gases (GHGs). In order to prevent the GHGs, the researcher implemented The RETScreen website that is utilized to carry out multiple analyses, such as investment, financial, greenhouse gas (GHG) risk and sensitivity, etc., on multiple systems, such as different kinds of power plants, commercial/institutional buildings, residential areas, industrial areas, individual levels, and so on.

Then, the researchers in [10] investigated that the majority of developing nations are unable to generate sufficient amounts of energy to satisfy the requirements of their populations, and the majority of the facilities that generate power are of the traditional kind. The use of renewable sources, particularly solar energy, has been receiving more attention due to the abundance of solar radiant energy in most of these countries and the cost efficiency of solar installations. This has led to some of the population opting for alternative sources of electricity to meet their domestic needs. This has led to some of the population opting for alternative sources of electricity to meet their domestic needs. Thus, to overcome this problem, they designed and developed a web-based application that assists in estimating the ratings and quantities of the components of the Solar Photovoltaic (PV) System which converts the solar energy to electrical energy that are required based on several factors, one of which is the particular climatic conditions of major cities in Nigeria. This application will be used to estimate the ratings and quantities of the components that are required.

Besides that, the researchers in [11] found that the ever-increasing demand for power is contributing to diminishing energy supplies. To ensure that can track the diminishing energy supplies, they proposed a web-based for measuring net energy use through the internet, using two PZEM 004T modules and an Arduino microcontroller. The real-time and online collection of the power and energy produced by PV systems is

accomplished via the use of a web-based net energy monitoring system. The findings of this study are initially expected to assist in obtaining the use of electrical energy as well as the energy generated by PV systems in real time and historical online data, which will be displayed on websites that can be accessed whenever and wherever, with the goal of optimizing the use of electrical energy in order to make it more efficient.

The researchers in [12] implemented a Web-SCADA to operate and monitor a hybrid power system operating on a smaller scale. Web/SCADA is a supervisory control and data collection and visualization software package that runs in a browser. Complex industrial procedures may be automated with its help, making them more manageable in settings where distant activities are required. The main Web-SCADA display shows a graphical animation of the managed hybrid power system as well as the monitored environmental and electrical data. The meter animation displays are used to represent the hybrid power system's current, voltage, and power. The meter animation display is used to visualize wind speed in the wind power subsystem. A meter animation display visualizes solar irradiation in the solar power subsystem.

The researcher in [13] found out that data acquisition, more often known as DAQ, is an essential component of many contemporary electronic systems, and photovoltaic (PV) systems are not an exception. DAQ involves the monitoring and logging of data. Photovoltaic systems are becoming increasingly popular due to their relatively moderate cost and low maintenance requirements. This popularity is being fueled by the recent surge and interest in renewable energy sources (RES), which has been fueled by rising prices for fossil fuels and increased environmental concerns. Thus, the researcher came out with the ideas of designing and developing a basic embedded web server that may be used for remote monitoring of a variety of electrical and electronic equipment, including a photovoltaic-based small scale power system as in order to demonstrate the viability of the idea of remote monitoring of a power system based on solar cells, a straightforward method was used to test the system. To test the system, signals were transmitted to the system over the internet, and signals were received over the internet from a simulated photovoltaic power plant.

Then, the researchers in [14] focused on the construction of a web-based monitoring and control system for the integration of two wind induction generators, a photovoltaic system, and a battery unit by utilizing an industrial programmable logic controller (PLC) with internet connectivity. As results, the web-based monitoring and control system that has been proposed is capable of being efficiently used to a variety of renewable energy sources that are located in remote places.

Besides that, the researchers in [15] stated that along with sustenance, a safe place to sleep, and clean drinking water, energy is one of the most basic requirements for human survival. They implemented the research method such as the photovoltaic solar system's primary function is to convert sunlight into usable electricity. It is a collection of parts that can be used to set up a functional system, such as a panel that can convert sunlight into electricity after it has been absorbed by it, an inverter that can change the output from direct current (DC) to alternating current (AC), a battery bank that can store energy, mounting structures, cabling, and other accessories. This collection of parts is known as a solar power system. The size of a photovoltaic (PV) system is determined by a number of different elements. In order to size the PV system, it entails the creation of algorithms, the creation of flowcharts, and the creation of web applications with programming in various languages. This software includes hypertext machine language (HTML), which was used to create and structure the webpage, cascaded style sheet (CSS), which was used for styling the webpage, JavaScript (JS), which was used for performing arithmetic functions, hypertext preprocessor (HP), which was used for the backend structure, and my structured query language (MySQL), which was used for database. By using

those web application, the PV sizing can be easily sized.

Furthermore, the researchers in [16] found that the requested power is determined by the technological process and the availability of renewable energy sources. In this research, primary goal of this study is to explain the approach and implementation of the monitoring and load control procedures of an electrical commercial consumer system that uses renewable energy sources in an off-grid power network configuration. The method that they used is a microcontroller development board, dedicated sensors for detecting system parameters, and an Ethernet connection module for the web server, which is hosted and streamed by the microcontroller as an HTML type web application. The main goal of the web application is to display the measured voltage, amperage, power consumption, and state of the solar PV charger in real time. This web application allows you to manually turn on and off electrical loads as well as change settings based on distance. Then, the web application is generated in real time by the microcontroller and is viewed via an internet browser.

The researchers in [17] concluded that solar power generators are gaining popularity due to their economic value and diminishing fossil fuel supplies. The economic worth of a solar power generator is determined by its ability to harvest power. Thus, they proposed a web-based monitoring system for displaying the performance parameters of power electronic equipment in a solar power generation system. The power flow parameter, which may be computed based on the voltage and current, is used to monitor the performance of power electronic devices. By applying the web-based monitoring system, it be able to detects system failures or performance degradation by comparing output power to projected input power from the environment aspect.

III. ADAPTIVE NEURO-FUZZYINFERENCE SYSTEM (ANFIS) IN PV

The grid integration of PV power has become a topic of research interest due to climate change and global warming [18]. Findings show that the results of forecasting models depend on forecasting horizon, available data, and method employed for the forecasting. The global capacity of installed PV power has increased from 5.1 to 227.0 GW in the last 10 years. The performance of a forecasting model is highly dependent on the correlation of the input and output values of the model. Researchers have classified the forecasting of PV power generation in different categories based on different factors. The study involved 4 Australian solar datasets. The performance of various recent forecasting methods were studied and compared against different factors, such as accuracy, reliability, computational cost, and complexity. Data shows that the optimized algorithm significantly improved the forecasting accuracy of the model. Based on recent studies, Artificial Neural Network (ANN) and Support Vector Machine (SVM) based forecasting models has been proved to performed well under rapid and varying environmental conditions. The accuracy of the PV power forecasting model varies by changing the forecast horizon, even with identical forecast model parameters.

Next, prediction of solar direct beam transmittance derived from global irradiation and sunshine duration using Adaptive Neuro-Fuzzy Inference System was studied [19]. This research was done regarding application of models to estimate the transmitted fraction of direct solar irradiation into normal incidence (Ktb). Hence, ANFIS was used to estimate Ktb. The models have been validated by using two databases, which are called the typical year and the atypical year. ANFIS was used due to its flexibility to estimate value of Ktb to be same as input variable as statistical models and other combinations. ANFIS provides accurate predictions and outperforms the statistical models. Despite the success of its application in certain areas, Adaptive Neuro-Fuzzy Inference System has been only partially used for solar modeling since it is frequently applied to problems

related in prediction of data. As a result of that, there were 140 decomposition models through observations included in the study.

A model has been developed by using Adaptive Neuro-Fuzzy Inference System to predict the PV module output power for any weight, and any particle size of coal dust deposited on PV modules [20]. The dust weight was chosen as 5 g, 10 g and 15 g in each particle size to create artificial pollution. Experimental results of polycrystalline silicon PV modules under Standard Test Conditions were shown. Electric power production of Turkey was 297.277,5 GWh in 2017. The proportion of renewable sources in the production of electricity power in 2017 was 29.35%, and 3.31% of this was solar powered. The aim of this study is to develop a model to predict the PV module output power for any weight, and any particle size of coal dust deposited on PV modules. The effect of coal dusts on PV module performance was studied within laboratory conditions. It has been found from the studies that influence of some pollutants on PV modules is limited. Hence, new types of pollutants were suggested for further research. The performance of ANFIS model in estimation of power output were quite successful while considering weight of particle size of coal dust.

A study aims to predict monthly solar radiation using ANFIS-PSO (particle swarm optimization), ANFIS-GA (genetic algorithm) and ANFIS-DE (differential evolution) algorithms as well as standalone ANFIS model [21], It was started by training the basic adaptive neuro-fuzzy inference system using the measured data such as sunshine duration, ambient temperature, rainfall and clearness index. These data was chose based on its availability and strong correlation to solar radiation. The results obtained demonstrate the high capability of adaptive neuro-fuzzy inference system in predicting the global solar radiation as well as the ability to be combined with other soft computing techniques. In addition, basic ANFIS model exhibits the fastest execution time overall other models. Therefore, extending the spatial database for monthly global solar radiation using the proposed hybrid models could be an area for future work.

For this study, models such as the adaptive neuro-fuzzy interface system (ANFIS), radial basis function neural network (RBFNN), and multi-layer perceptron (MLP) are employed to estimate solar radiation [22]. In semi-dry, dry, and wet climates, monthly sun radiation is projected. To increase the performance of ANFIS, RBFNN, and MLP models, the Grasshopper algorithm (GOA) is used. Rasht (humid climate), Yazd (semi-arid climate), and Tehran (slightly arid environment) are regarded case studies in Iran. GOA's accuracy is compared to particle swarm optimization (PSO) and the salp swarm technique (SSA). The optimal input combination at these three sites is relative humidity, wind speed, rainfall, and temperature, according to the results. In order to construct new hybrid ANFIS models for estimating monthly solar radiation in various regions, a research paper was written. Furthermore, the impacts of various parameters on solar radiation are thoroughly explored. Temperature appears to be the most efficient measure for measuring solar radiation in dry and semi-arid climates, according to research. The fundamental conclusion of this research is that the most appropriate input scenario for estimating solar radiation must be determined because different input scenarios in different climates produce varied results. Other models and inputs do not provide the same level of precision as GOA. Temperature is found to play a crucial influence at the Yazd station, which has a dry climate. Solar energy reduces greenhouse gas emissions while also reducing reliance on fossil fuels. It is one of the most cost-effective power generation options for a long-term, prosperous future.

ANFIS also can be used to track Maximum Power Point (MPPT) using FPGA for photovoltaic system [23]. A current mechanism based techniques like incremental conductance method and observe method are efficient but they are less stable, more oscillatory about MPP and sensitive to a high frequency noise. The suggested ANFIS-reference

model controller is efficient since it has been trained offline using Matlab tool with practical data sets. The results reveal that the ANFIS-reference model controller that was based on zero order Sugeno fuzzy model has more efficient and better dynamic response than the incremental conductance method and constant voltage method. Based on the findings from this study also has concluded that ANFIS reference model methods can accumulate higher daily energy than constant voltage method during maximum ambient temperature.

Maximum power point tracking methods (MPPT) algorithm was needed to enhance the operation of PV systems [24]. However, this conventional method cannot function well in abruptly changing atmospheric conditions. Hence, another MPPT algorithm was developed by utilizing incremental conductance (INC) technique along with hybrid crow and pattern search (HCS-PS) algorithm based ANFIS. ANFIS was a tools that has learning potential of neural network according to takagi-sufeno type FIS hypothesis knowing for improving the efficiency of intelligent system. The optimal voltages of PV systems can be determined by employing hybrid HCS-PS with the considerations of temperature and solar irradiance. Those values are used as input-output training information set in ANFIS in the first step. Simulation results from the study proved that HCS-PS-ANFIS-INC method can definitely raise the output power under different circumstances. The strategy responds actively during the high level of solar irradiation.

The PV power forecasting with hybrid methods such as ANFIS model is more accurate than other methods [25]. ANFIS model specifically can predict and analyze the energy, cost, and cost-effectiveness that will occur in the future. PSO-Artificial neural network models were verified accurate with mean square error. Through this article, prediction of PV power output were involving Thailand area by using one-year of electrical data. The results shows comparison between accuracy of ANFIS model (99.8532%) and PSO-ANN (98.9157%). Other than that, ANFIS model also can predict energy, cost and cost effectiveness that can minimize time for the project planning. The study has recommend that future research on forecasting PV power output in new method and application of data improvement with small deviations to make results more accurate.

Another project related to global solar energy where the proposed model has been trained. The total analysis indicated that by using an ANFIS-based model, the error has been greatly decreased for each of the climate zones across the country [26]. Because of the high cost of the instrument, maintenance, sufficient duration of the record, and calibration of the measuring equipment, data based on solar energy resources are unavailable. The development of a model based on easily available data to anticipate global solar energy has become necessary. The study claim that meteorology, renewable energy, and solar energy are all feasible applications of the suggested model. ANFIS-based model has been developed for forecasting global solar energy using meteorological characteristics for various weather conditions such as clear sky, hazy sky, hazy and cloudy sky, and cloudy sky, and has been effectively applied to various climate zones around the country. The ANFIS-model was validated using unknown test data that had never been seen previously by the model.The total analysis indicated that by using an ANFIS-based model, the error has been greatly decreased for each of the climate zones across the country.

The ANFIS modelling method was evaluated fo predicting solar still productivity (SSP) [27]. To find the optimum ANFIS model for SSP modelling, researchers trained, tested, and validated a variety of ANFIS models with various membership functions (MFs). The ANFIS models were trained with 70% of the available data, tested with 20% of the data, and verified with the remaining 10% of the data. The results show that the ANFIS method for modelling SSP is extremely accurate, effective, and dependable. Pi-shaped (PIMF) and triangular (TRIMF) were shown to be the best MFs in all modelling stages for ANFIS

models based on statistical performance criteria. In the modelling procedure, the best results are produced using PIMF. It is hoped that the results will serve as a reference for future attempts to assess the used parameters in this investigation using other soft computing methodologies to forecast SSP.

There was research regarding a comprehensive assessment of solar radiation and solar energy prediction was conducted, as well as exploration of Artificial Intelligence domains such as Artificial Neural Networks and Fuzzy Logic [28]. A variety of ANN models with various methods and input parameters have been discussed. Because ANN models employ a vast quantity of data and have more parameters, they perform well in all climate circumstances when compared to other models. Sunlight and temperature are used as input parameters in a hybrid ANN model, which is nonlinear. According to the findings of the study, ANN and Fuzzy logic models are more successful for estimating than any other empirical models. Solar radiation and energy prediction algorithms are shown to be more reliant on input parameters. Finally, some potential study possibilities and areas for improving the efficiency of the outcomes were identified.

Yordanos Semero and colleagues (2018) wrote in their paper 'PV power forecasting using an integrated general algorithm GA-PSO-ANFIS approach and Gaussian process regression. Based feature selection strategy that this paper proposes an integrated GA-PSO-ANFIS based hybrid technique for short term photovoltaic power generation forecasting [29]. The fitness function is based on a Gaussian process regression model. The proposed technique's performance is compared to artificial neural networks, linear regression model (LRM), and persistence approaches. Solar energy's fluctuation creates operational challenges in the management of electricity supply networks. Increased use of weather-dependent energy sources like PV in such systems makes power control more difficult. To allow binary GA to reduce the number of input characteristics required for enhanced forecast modelling, a GPR model-based fitness function is created. ANFIS structure is then optimised for forecast modelling using an integrated GA-PSO algorithm. The suggested technique's performance is compared to that of ANN, LRM, and persistence approaches.

There was a study conducted where a robust version of a Convolutional Neural Network (CNN) integrated with Support Vector Regression (SVR) model has been developed to predict daily global solar radiation (GSR) [30]. A comprehensive comparison of the GSR prediction performance of CSVR and other deep learning (DL) methods as well as conventional machine learning (ML) models is carried out. The CNN model is used to extract local pattern features as well as common characteristics that reoccur in the time series at different intervals, and the SVR was used to predict the daily GSR at six solar farms in Australia, replacing the CNN's fully connected layer. Meteorological variables used as input from global climate models to build the hybrid CSVR model. The proposed deep hybrid CSVR model is compared to the performance of eight other DL and ML models.

The effectiveness of an intelligent technique of ANFIS-MPPT by comparison and analysis of the obtained results with others given by applying the conventional (Perturb & Observe) PO-MPPT method [31]. The simulations were performed using the software Matlab Simulink considering two PI controllers which are used to improve the system performance and reduce energy losses. The simulation results demonstrate that the ANFIS-MPPT is the fastest algorithm in tracking the maximum power of the PV panel which impacts the system ability. Thus, the ANFIS algorithm can be used as an effective tool to reduce the oscillations. On the other side, the Perturb & Observe block show constant oscillations nearby the MPP and causes significant energy losses to the organism. Moreover, the ANFIS command has shown better accuracy comparatively to PO command which cannot track the exactly MPP in some cases.

Solar power forecasting will have a significant impact on the future of large-scale renewable energy plants [32]. Predicting photovoltaic power generation depends heavily on climate conditions, which fluctuate over time. In this research, a hybrid model that combines machine-learning methods with Theta statistical method was proposed for more accurate prediction of future solar power generation from renewable energy plants. The machine learning models include long short-term memory (LSTM), gate recurrent unit (GRU), Auto-Encoder LSTM Auto-LSTM and a newly proposed Auto-GRU. To enhance the accuracy of the proposed Machine learning and Statistical Hybrid Model (MLSHM), two diversity techniques, was employed such as structural diversity and data diversity. To combine the prediction of the ensemble members in the proposed MLSHM, we exploit four combining methods simple averaging approach, weighted averaging using linear approach and using non-linear approach, and combination through variance using inverse approach..

IV. CONCLUSION

Based on the review that has been made, the Web Application Package and Adaptive Neuro-Fuzzy Inference System (ANFIS) algorithm has been used by recent researchers in PV research. The benefit includes forecasting a photovoltaic system model in efficient way and enhance the understanding in deep learning tools with its application for many aspects in engineering fields. For future research, more Artificial Intelligence method can be explore to be applied in forecasting a solar PV system. Next, data from the existing PV system can be used in future research on order to increase the accuracy of performance for deep learning methods in PV system.

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