Smart Loading Management System for Hybrid Photovoltaic/Wind Power Supply

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***Abstract*—Photovoltaic and wind turbine generation using environmentally friendly technology in the process of harvesting energy from the nature can be a solution for the future electrical energy crises so that they become most developed and reliable alternative. However, the conversion of solar/wind energy is highly dependent on the availability of sunlight and wind speed. Therefore, it is necessary to study the PV/wind loading which aims to increase and maintain the continuity of the electricity supply to the load. Load power management follows the availability of solar and wind energy in sunny, cloudy, rainy, or evening weather by considering the remaining usable battery voltage. Comparison of data is done to determine the system constraints with the ANFIS method. In testing stage, the ANFIS data performed with three membership function (high, medium, low). Based on 4003 data used in the training process, an error of 26% was found, after compared with the actual data. By using ANFIS obtained that there are more options for the maximum load that can be supplied by PV/wind generation. This has an impact on the performance of the hybrid PV/wind standalone which is more leverage on the loading side.**

Keywords— Smart management system, ANFIS load controller, and Hybrid renewable system.

I. Introduction

The utilization of renewable energy generation to reduce fossil fuel as well as the need for reduce carbon emissions will continue to increase in the future [1]. The use of electricity from renewable energy plants is predicted to be dominated by wind and solar power [2]. The solar generation used photovoltaic (PV) panels made up of silicon semiconductor material, to convert electrical energy from the sun. The output electrical power of the PV panel depends on the angle of incidence of sunlight and its radiation [3]. While wind power plants generate electricity by converting the rotation of the turbine blades into electric current using an electric generator. Wind energy arises from the circulation of the atmosphere by the activity of solar energy sources. So that the entire equatorial region will receive more solar radiation energy than the polar regions. This air movement is directly affected by differences in the type and pressure of the air or wind.

The advantage of solar and wind is renewable energy that does not run out, in contrast to conventional resources which are increasingly depleting [4]. These energies are environmentally friendly and does not cause emissions. These emissions are dangerous and can cause acid rain or greenhouse gases. Other advantages of using this energy are green energy by not polluting the surrounding environment [5]. This energy generation only takes a few meters to form the foundation of the wind turbine and some area for PV panels. With a smaller space, the remaining space can be used for other purposes such as agriculture.

The disadvantages of solar and wind energy are difficult to predict [6]. Solar and wind are natural energies that are unpredictable and cannot be relied on continuously [7]. Energy management and energy storage devices are generally used to smooth variations NRE generators output due to unpredictability resources [8]. Besides that, the use of energy from fossil fuels still has a big role and can be backup renewable resources [9], [10]. Nearly two-thirds of the electricity used still comes from coal, gas, and nuclear. Consideration of NRE electricity supply is still mixed in balance with fossil energy, because in NRE power plants there are intermittent or instability, because the electricity supply still depends on natural conditions and weather. So, to meet the electricity supply is still from fossil fuel plants.

Even though it is intermittent, now it can be circumvented by using smart grid and digitalization solutions. By using smart grid technology, electricity production from renewable energy plants and its control can be carried out remotely and centrally. However, research to obtain precise and accurate techniques and algorithms are still ongoing and will continue to be improved. In this paper, we will report the findings related to smart management of operation and household-scale PV/wind loading. Neuro Fuzzy-based technique is used to improve the decision on the loading of NRE generators in order to increase the continuity of the electricity supply.

II. ANFIS Loading Manajement System

Neuro-Fuzzy is a combination of fuzzy logic systems and artificial neural networks. The neuro-fuzzy system is based on a fuzzy inference system that is trained using a learning algorithm derived from an artificial neural network system. Where, the advantage of the fuzzy inference system is that it can overcome linguistic problems while the advantage of the artificial neural network is that it can solve problems through a learning and training process so that it can predict future events. Thus, the neuro-fuzzy system has the advantages of the fuzzy inference system and the artificial neural network system. From its ability to learn, the neuro-fuzzy system is often referred to as ANFIS (Adaptive Neuro Fuzzy Inference System).

In this paper, the use of ANFIS is introduced. The ANFIS is used has the same architecture as the rule base fuzzy Sugeno model [11]. With membership values being linguistic labels (such as "small" or "large"), pi, qi, and ri are consequent parameters.

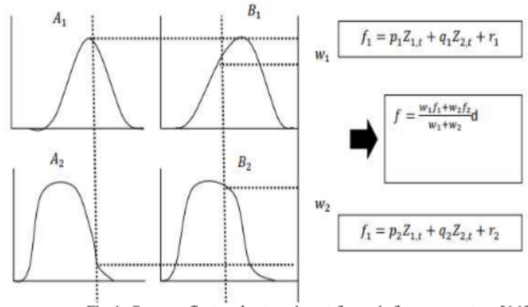

Fig 1. Sugeno first-order two-input fuzzy inference system [11]

Sugeno first order with two input ANFIS is shown in Fig. 1.

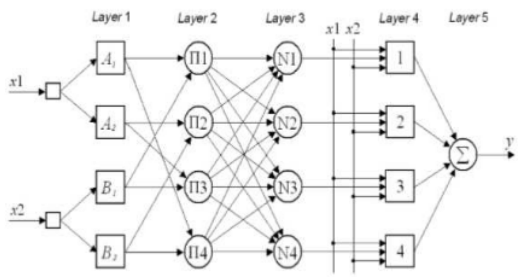

Fig 2. ANFIS architecture [12]

Fig. 2 shows the ANFIS architecture which has five layers and each layer has a node. The node in the ANFIS architecture consists of an adaptive node (symbolized by a square) and a fixed node (symbol by a circle). The process of updating parameters in ANFIS, uses a two-way learning algorithm.

TABEL 1 TWO PATHS OF HYBRID LEARNING IN ANFIS [13]

	Forward Pass	Backward Pass
Premise Parameters	Fixed	Gradient descent
Consequent Parameters	LSE	Fixed
Signals	Node Outputs	Error signals

In this paper loading management based on ANFIS is developed, shown in Fig. 3. The input parameters of ANFIS controller are charging current from PV, WT and battery terminal voltage. The output is loading status and control signal to activate solid state relay. The loading status comprise of maximum loading system of 200 W, 600 W or 800 or switch off to grid utility as backup power supply.

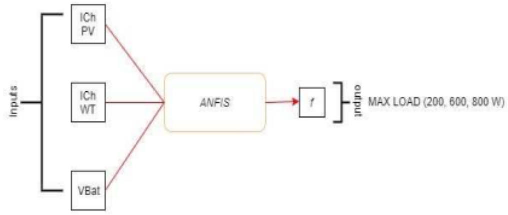

Fig 3. Proposed ANFIS loading management system.

III. METHODOLOGY

A. System Design

This research is based on the source of electricity generation using new renewable energy-oriented to solar energy and wind energy. The generation of electrical energy using this new renewable energy will use 3 parallel solar panels @ 310 Wp then there is one wind turbine with a capacity of 1 kW using the Homaya Solar Hybrid System 1500 inverter with 2 vrla @ 100Ah 12V batteries. The system will be designed to be loadable up to 900 VA household scale.

The design model of the operating and loading management system for household-scale power plants is in Fig. 4. The operating and loading management system for household-scale power plants will follow the time and function automatically using the Arduino microcontroller control. DC current and voltage sensor module is used to get charging current and battery terminal voltage. Management of the operation and loading of this household-scale hybrid power generation system can be seen in Fig. 4. Operating system and loading of this hybrid power generation system.

B. Loading Management Process

In this study, a smart automatic transfer switch for a hybrid PV system and Wind Turbine was designed as the main source and the State Electricity Company (PLN) as a backup source. PV and Wind turbines will store the power generated into the battery. By reading the battery output voltage, information is obtained about the remaining power in the battery. The PV battery and Wind Turbine are connected to the voltage sensor. The output voltage of the PV and WT batteries will be read by the voltage sensor module, the input for the Arduino Mega 2560. Meanwhile, the DC sensor will read the output current from the PV and WT, which becomes the input for the Arduino Mega 2560.

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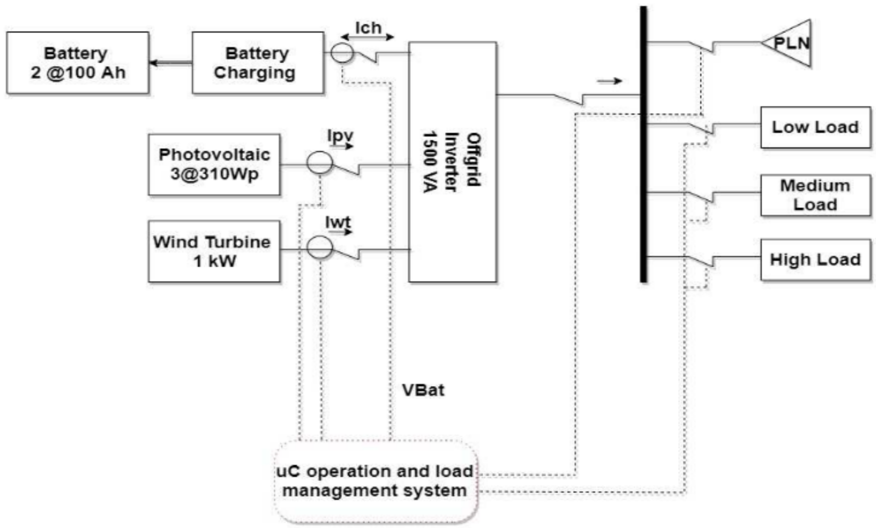

Fig 4. Schematic Diagram of Operation and Load Management System

The voltage read by the voltage sensor will be input to Arduino then the output current from PV + WT which is read by the DC sensor will also be input for Arduino Mega 2560. Where when the battery voltage is read by the sensor the voltage is more than 24.89 V and the output current (Ihybrid) which is read by the current sensor is less than 24 A then the high load line (max 800 W) is activated. If the battery voltage read by the voltage sensor is less than 24 V and the output current (I_{hybrid}) read by the current sensor is less than 14.4 A, the line switches to a medium line (max 600 W). Meanwhile, if the battery voltage read by the voltage sensor is less than 22.30 V and the output current (I_{hybrid}) read by the current sensor is less than 7.2 A, the line switches to a low line (max 200 W). When the battery output voltage is read by the voltage sensor less than 21 V, the backup source from PLN will be activated to support the work of the system.

In this study, solid state relays will be used to transfer load switches, where 4 solid state relays will be used. The solid state relay which is equipped with an LED indicator will show which load-lines can be served by the system and whether it has used a source from national utility which is a backup energy source in this system. Testing of this system was carried out at an off-grid Hybrid (PV + WT) power plant majoring in electrical engineering at Andalas University so that it can be seen whether the system works well in transferring electrical energy supply.

This system will also be tested using the ANFIS (Adaptive Neuro-Fuzzy Inference System) testing scheme. This is done to find out whether system performance can increase if ANFIS is applied to the system. The first step is to collect input data (battery voltage and charging current from PV + WT) which then become parameters to obtain load line output that can be served by the system and the selection of energy supply sources from PLN. The next step is to collect test data which will later be compared between the actual data and the output data from ANFIS.

IV. Result and Discussions

The experimental results of measuring PV and WT charging currents, each of which has specifications for PV as much as 3 x 310 Wp and WT as much as 1kW. This Hybrid (PV+WT) system produces outputs that fluctuate according to weather conditions in PV and wind speed. In the picture below, it can be seen that the output of the hybrid system (PV+WT) can work well and serve the load according to the parameters that have been set. The weather conditions at the time of data collection were relatively sunny and the wind speed was 1.1 m/s to 4.7 m/s starting from 10.27 to 15:58, the charging current from PV and WT was quite large and capable of serving large loads while simultaneously charging the battery optimally. However, the amount of charging current can change and is largely determined by conditions (weather and wind speed). Fluctuations in charging current also occur because the sun's rays are blocked by clouds even though it is bright, and the wind speed changes.

The operation design mechanism and load management of this Hybrid system have several parameters that are used as inputs to influence the output in the selection of the maximum load channel that can be served by the system. The input parameters that can affect the output in the selection of the maximum load channel that can be served by the system will be predicted by the ANFIS smart system. ANFIS will provide predictions according to the data obtained when conventional testing is carried out. The data obtained will be used as a benchmark for input parameters to influence the output in the selection of the maximum load. The maximum load that can be served by the system will be more varied and precise. This is because the data obtained and trained in the ANFIS system will recognize the input parameters, then provide accurate predictions about the output (maximum load that can be served by the system) according to the state of the input parameters.

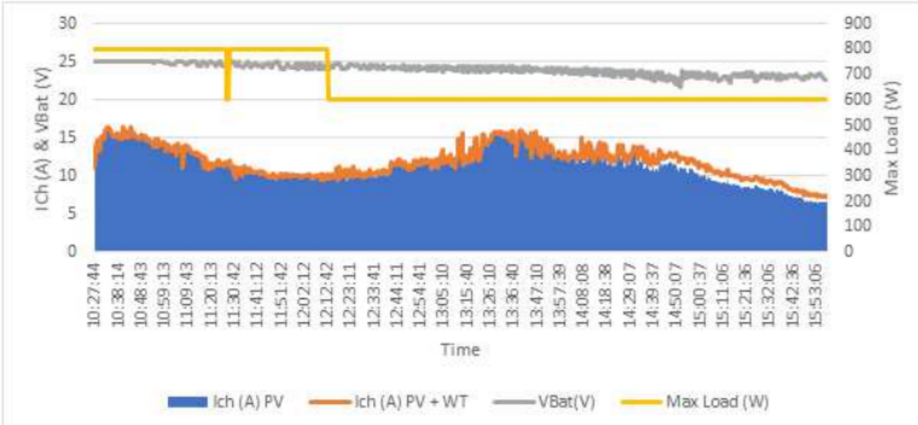

Fig 5. Graph of Operational and Loading Management Testing for Hybrid Systems July 17, 2021

The graph in Fig.5 shows that the operating and loading management of the hybrid system (PV+WT) works well and is able to serve the load according to the parameters that have been set. It can be seen that the charging current generated when it is loaded and at the same time charging the battery can serve the maximum load according to the parameters. WT data was obtained through the HOMER application referenced from NASA. The data obtained from the HOMER application is updated hourly. Then to get the data in accordance with the PV data, it is done by the linear interpolation method.

In Fig. 5 it can be seen that by using ANFIS in the system, there are several additional options for the maximum load that can be served by the system based on predefined parameters.

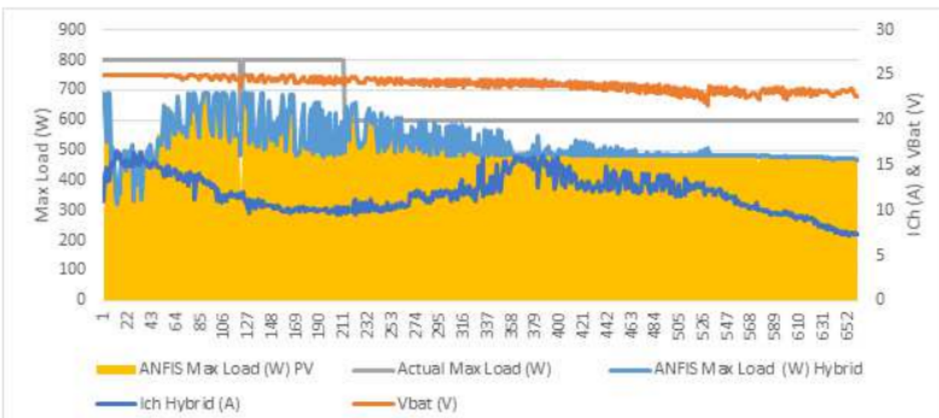

Fig 6. Comparison Graph of Actual Max Load and Max Load ANFIS July 17, 2021

Looking at the graph in Fig. 6, it is very clear that the max load ANFIS has more options for the maximum load that can be served when the Charging Current and Battery Voltage are under certain conditions. This is certainly an increase in system performance which has an impact on the continuity of supply from the hybrid system to the maximum load that can be served.

V. Conclussion

This hybrid power system operation and loading management system have been designed according to sunny, cloudy, rainy, or night weather conditions and wind speed. The battery charging current and battery voltage are the working parameters of the control system to activate the solid state relay in selecting the maximum load that can be served by the system or vice versa. During the day with sunny conditions and a fairly high wind speed, the charging current for the battery will be maximized while being able to serve high loads. From the data obtained, if the system is run conventionally, the actual data generated is in the form of High, Medium, and Low Loads. Meanwhile, when compared with the use of the ANFIS method, the maximum load that can be served by the system is more varied. This causes the system to be better at selecting the load line according to the parameters in certain circumstances. Suggestions for this research for the future are to use WT that has been installed in a predetermined place to get data that is in accordance with the actual conditions.

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