Automatic Transfer Switch System for Controlling the Energy Utilization in Greenhouse Mobile Robot using Neural Network Algorithm

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Abstract. A greenhouse is a building specifically designed to cultivate plants in both conventional plants with soil media and modern cultivation. However, there are problems that must be faced, such as the disturbance of pests. It requires a mobile robot that can monitor and secure the plants. The purpose of the surveillance is to ensure that plant growth runs smoothly, from planting to harvesting, without pest disturbance. The greenhouse mobile robot is designed using a solar panel and battery that are regulated by an automatic transfer switch (ATS) to automate the switching of the two sources of electrical energy. The neural network aims to improve the performance of ATS in making decisions by processing voltage sensor data in Arduino Mega 2560 through independent training, resulting in an MSE value of 0.003001. The results of the ATS system show success in making a decision so that the greenhouse mobile robot can continue to operate independently using solar panels and battery alternately. It contributes to the efficiency and reliability of the robot without interruption of electrical power problems that can stop its operation.

Keywords: Mobile Robot, Neural Network, Energy Alternative.

1 Introduction

Basically, robot is designed to assist and reduce direct human involvement from the activity with high attention, hard and unsafe work environments, such as carrying heavy goods, securing, searching, monitoring, rescuing and other activities concerned for managing time and improving services in daily activities [1]. Due to the many benefits of robot, especially mobile robot, it has been widely implemented in many applications such as the automotive industry, education and research, healthcare facility, construction, agricultural, military and others. In addition, the rapid development of artificial intelligence technology has a vital role in order to create smart mobile robot and strongly supports the mobile robot become more efficient and reliable. [2–4].

One of the implementations of mobile robot is to protect the greenhouse environment from pest damage. It is designed for monitoring and securing the plants using alternating electrical energy sources, solar panel and battery. Solar cells are devices that can

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convert sunlight energy into electrical energy with the principle of the photovoltaic effect due to the relationship or contact of two electrodes connected to a solid or liquid system when getting light energy [5].

In reality, mobile robot that use solar panels are constrained by sunlight. When the weather is cloudy the production of solar irradiance is low, but the mobile robot still needs power to move. [6] In its application, the solution to this is that a device is needed that can convert the main supply from the solar panel to the backup supply, the battery automatically. [7,8] The automatic process of transferring between these two sources, uses an automatic transfer switch (ATS) so that the mobile robot can continue to operate independently without power interruption [9].

In this research, the automatic transfer switch used utilizes artificial intelligent, a neural network algorithm. The main characterstic of artificial neural network is the ability to learn. The learning process can be interpreted as interconneting weight by a cell. Applying a neural network algorithm allows the ATS to minimize errors, and to predict the output of the electrical energy source to be used. [10] This mobile robot is placed outdoors and gets energy from the solar panel that can absorb sunlight. This system allows to change the portion of electrical energy supply automatically by paying attention to the condition of the battery. So that the robot can use power from solar panels when it is sunny and use power from batteries during periods of low solar irradiance automatically.

2 Proposed Design and Method

2.1 Software Design

The design of this study is divided into two parts, software design and hardware design. Software design is a technique related to systematic software design, including software development and modification. The diagram block is an important part of the design generally of the device because it represents a system that can be operated or work.

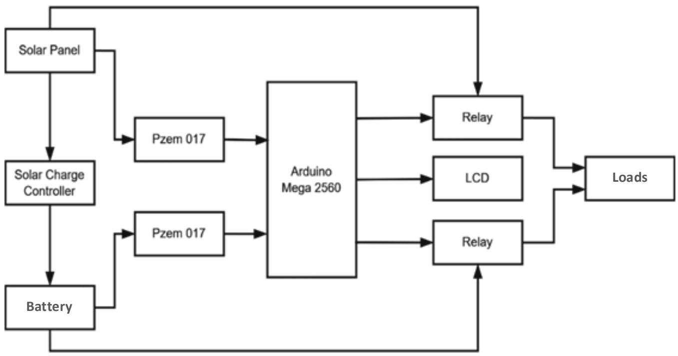

Fig. 1. The diagram block of the Automatic Transfer Switch (ATS).

Flowchart is a form of system work flow that is an important part of planning a tool and describes how the system works.

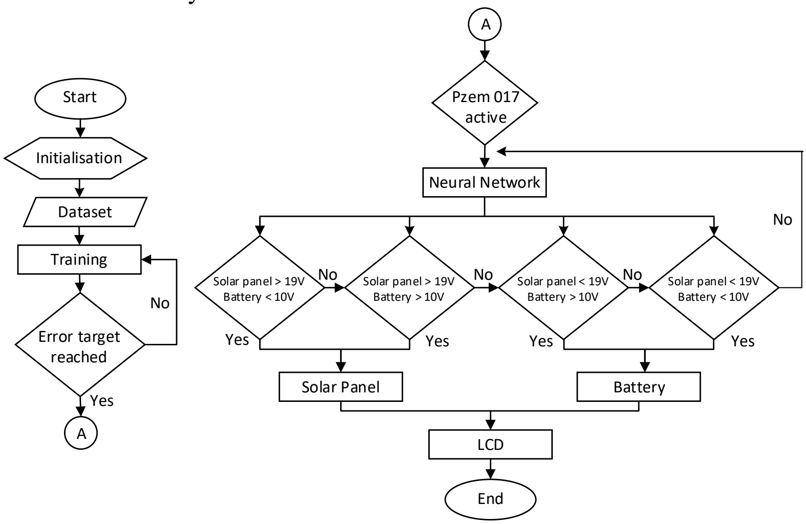

Fig. 2. The flowchart of the Automatic Transfer Switch (ATS).

A Neural network is used as the method of the automatic transfer switch to make the right decision to use solar panel, and battery alternately. The method was chosen because it is effective in processing and learning more than one type of input. In addition, it can produce some outputs and provide accurate results [11].

NNs have several common components or structures that are often found:

1. Input Layer is the first layer of the network consisting of independent variables (X1, X2, ..., Xn) which are input signals to the NN.
2. The hidden layer is a layer between the input layer and the output layer consisting of (Z1, Z2, Z3,...., Zn) whose number varies depending on the desired decision. Hidden layer functions to process input data and perform mathematical calculations.
3. The output layer is the last layer of the NN consisting of (Y1,...,Yn). Each neuron in the output layer represents the resulting output or prediction.
4. Neurons are the individual processing units in the network. Each neuron receives one or more inputs, performs mathematical calculations and produces an output.
5. Weight is a parameter that connects neurons in the network to improve prediction accuracy. The weight is the input weight to the hidden layer denoted (Vij) and the hidden layer weight to the output layer denoted (Wjk).
6. Activation function is a mathematical function applied to each neuron in the neural network layer to introduce non-linearity into the model. The activation function used in this research is sigmoid.

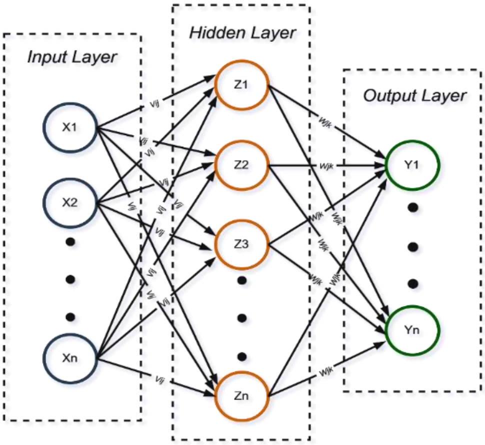

Fig. 3. Neural Network Architecture

Figure 4 is a neural network architecture of the Multi-Layer Perceptrons (MLP) type. In the neural network architecture, there are 2 input neurons (input layer) used, namely input neuron VS1, which is a voltage sensor (Pzem1) as a voltage detector on the solar panel, while input VS2 is a voltage sensor (Pzem 017) as a voltage detector on the battery In addition, there are 4 neurons in the hidden layer in charge of processing data and transforming input data (input) into output data (output). Output neuron 1 (RS) is relay 1 to connect the load to the solar panel, while output layer 2 (RB) is relay 2 to connect the load to the battery.

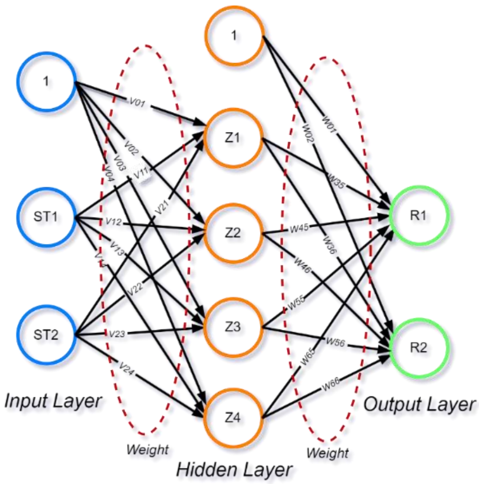

Fig. 4. Neural Network Architecture of the Multi-Layer Perceptrons (MLP)

2.2 Hardware Design

Hardware design includes the stages of planning an electronic and mechanical device. Planning is the most important stage of the entire process of making tools. The goal is to get the desired end result by paying attention to components that are easily available. Using this planning makes it easier to find and repair the damage. In addition, good planning will produce results to themaximum.

The automatic transfer switch circuit between the solar panel and battery on the security robot consists of a Pzem 017 sensor, arduino mega2560, relay and LCD then combined into an overall circuit schematic.

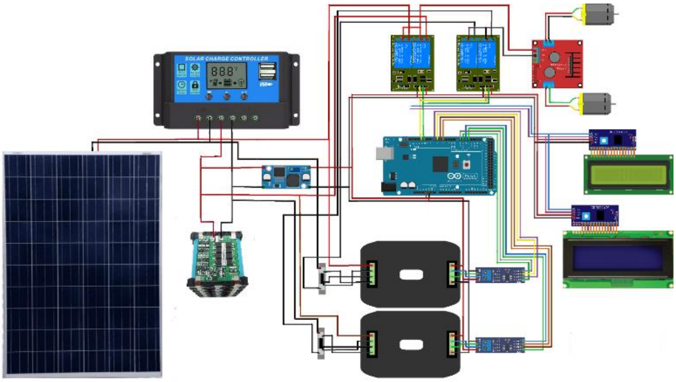

Fig. 5. Circuit Schematic

The robot design is equipped with a solar panel that is placed on the top and the battery is placed inside the robot. In addition, there is an automatic transfer switch circuit consisting of a Pzem 017 sensor, relay, LCD, stepdownLM2596, and Arduino Mega.

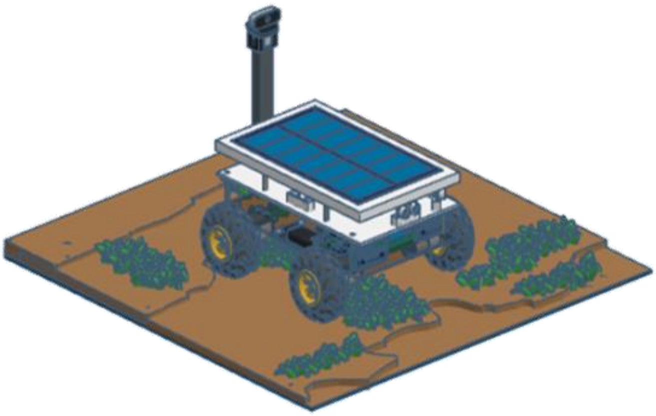

Fig. 6. 3D design of greenhouse mobile robot

3 Result and Discussion

3.1 Data Set Training of NN

In software testing of neural network testing data, namely conducting the NN training process, NN training results, and also testing NN performance. The goal is to find out and optimize NN as a method used by the automatic transfer switch (ATS) when determining predictions. It aims to ensure that the ATS functions properly under varying voltage conditions.

The training data set to determine the output prediction of relay 1 (RS) and relay 2 (RB) is based on input data from voltage sensor 1 (VS) on the solar panel and voltage sensor 2 (VB) on the battery. NN training is done using the backpropagation algorithm and the voltage data is modified so that it can be processed by the neural network algorithm on the Arduino mega 2560 as shown in table 1.

Table 1. Data Set Training of NN

VS	VB	Output Prediction	
		RS	RB
0	0	0	1
1	0	1	0
0	1	0	1
1	1	1	0

Table 1 is a neural network training data set containing four scenarios based on the condition of the output voltage of the solar panel and battery on the robot. The purpose of the training data is to train the NN to recognize and understand the relationship between voltage values to determine the choice of deciding to activate relay 1 or relay 2.

1. In the data set to determine the condition if VS is 0 or detects the solar panel voltage < 19 Volts and VB is 0 or detects the battery voltage < 10 Volts, the predicted output RS is 0 or off and RB is 1 or on.
2. In the second training to determine the condition if VS is logic 1 or detects solar panel voltage > 19 Volts and VB is logic 0 or detects battery voltage < 10 Volts, the predicted output of RS is logic 1 or on and RB is logic 0 or off.
3. In the third training to determine the condition if VS is logic 0 or detects solar panel voltage < 19 Volts and VB is logic 0 or detects battery voltage > 10 Volts, the predicted output of RS is logic 0 or off and RB is logic 1 or on.
4. In the fourth training to determine the condition if RS is logic 1 or detects solar panel voltage > 19 Volts and RB is logic 1 or detects battery voltage > 10 Volts, the predicted output RS is logic 1 or on and RB is logic 0 or off.

3.2 Result Training of NN

In the study, data on the results of NN training were obtained. The data includes data on the results of updating weights and mean squared error (MSE) obtained from 574 training iterations. Each iteration takes an average of 0.3 seconds, according to the settings implemented in the NN library, with a learning rate of weights = 0.33 The final result achieved is a low MSE value of 0.003001, in accordance with the target MSE value that has been set > 0.003.

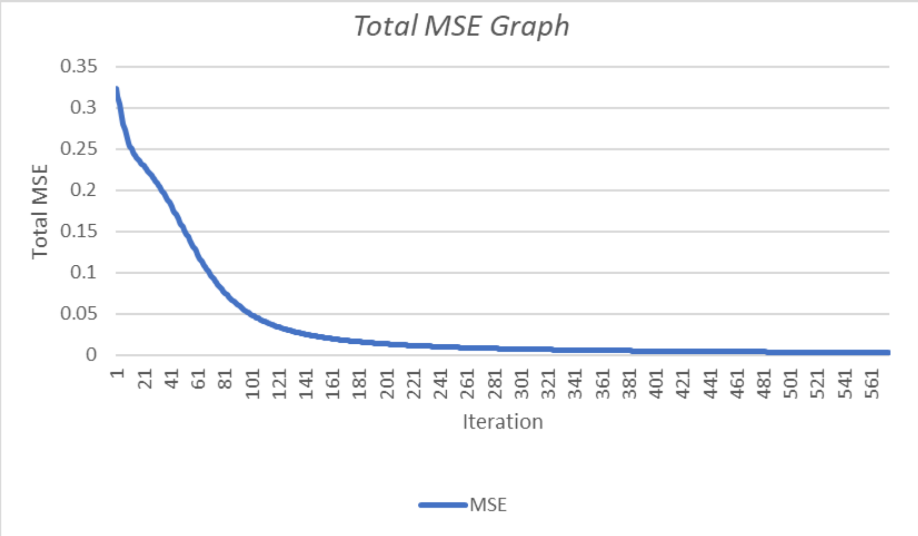

Fig. 7. Mean Square Error (MSE) graph

The mean squared error (MSE) graph shows a pattern of decreasing MSE values with consistency at each iteration, until finally reaching the lowest MSE target value. The lowest MSE target value, 0.003001, was achieved at the 574th iteration. The success in achieving the MSE target and the consistent pattern on the graph indicate that the neural network (NN) training process has been successful. The results show the ability of the NN to adapt to the dataset and produce predictions that are increasingly close to the true value as the iteration process progresses.

3.3 Result of NN Testing

NN testing is done by provide the voltage data at the NN input. The test is to see the relay condition in accordance with the prediction that has been determined. The results of the relay condition are obtained from the detection of the ST1 voltage sensor on the solar panel and the ST2 voltage sensor on the battery which is installed directly at the output point of the solar panel and battery output so that the prediction error can be seen.

Table 2. The result of NN testing

Testing	VS (V)	VB (V)	Relay Condition		Relay Prediction	
			RS	RB	RS	RB
1	18.41	12.3	0	1	0	1
2	17.55	10.27	0	1	0	1
3	20.6	11.27	1	0	1	0
4	20.9	11.15	1	0	1	0
5	20.1	11.1	1	0	1	0
6	20.4	10.87	1	0	1	0
7	19.5	10.12	1	0	1	0
8	19.56	10.59	1	0	1	0
9	19.3	9.8	1	0	1	0
10	17.5	9.56	0	1	0	1

Data results are obtained from several NN tests. From these tests obtained data on the results of relay conditions using 2 voltage sensors. Where, with NN test data when VS detects a voltage of 17.5 Volts - 20.4 Volts and VB detects a voltage of 9.56 Volts - 12.3 Volts, the relay condition is obtained according to the prediction of the predetermined output.

3.4 Result of ATS Testing

Testing the automatic transfer switch on the robot is testing when the ATS decides to use solar panels and batteries to supply voltage, and current to the load. Where it is set if the voltage> 19 Volts decides to use the solar panel and if < 19 Volts decides to use the battery. Tests are carried out when the robot is on but not in the condition surrounding the greenhouse and when the robot is on in the condition surrounding the greenhouse.

Table 3. The result of ATS testing

Irradiance (W/m^2)	Weather	Solar Panel			Battery			Condition
		V	I	W	V	I	W	
532.2	Cloudy (26°C)	9.5	0	0	11.96	2.3	27.5	On, Battery
692.6	Cloudy (28°C)	17.6	0	0	11.4	1.54	17.5	On, Battery
889.4	Sunny (32°C)	20.45	0.2	4	11	0	0	On, Panel
870.3	Sunny (31°)	20.01	0.09	1.8	10.8	0	0	On, Panel
783.9	Sunny (30°)	19.91	0.04	0.7	10.5	0	0	On, Panel
689.3	Cloudy (28°)	18.41	0	0	11.27	1.2	13,5	On, Battery
663.8	Cloudy (28°)	17.55	0	0	11.15	2.25	25.0	On, Battery
854.3	Sunny (31°C)	20.27	0.09	1.8	11.1	0	0	On, Panel
997.1	Sunny (31°C)	19.54	0,06	1	10.9	0	0	On, Panel
783.6	Sunny (31°C)	16.77	0	0	10.2	0.69	7.0	On, Battery

From the results of the ATS test data that weather conditions affect the ATS to connect the load to the solar panel or battery power supply. When the robot is not moving, the ATS chooses to use the solar panel to supply the load during sunny weather conditions. In those situations when the weather conditions are cloudy, the ATS chooses to use the battery.

However, when the robot is moving inside the greenhouse, the ATS decision chooses the solar panel when the weather is sunny. However, the discharging current of the solar panel is lower. Consequently, there is a slowdown in the movement of the greenhouse robot. Meanwhile, ATS chose to use batteries when the robot's position was sometimes obstructed by the shadow of the greenhouse or when the weather was cloudy. This decision allows the robot to move around the greenhouse without being constrained by the surrounding environmental conditions.

4 Conclusions

In the implementation of neural networks as a method in ATS, training process with a total of 574 iterations to optimize the weight and achieve the targeted Mean Squared Error (MSE) value, which is 0.003001. The test results on the NN that has gone through the training process show the conformity between the relay conditions generated with the prediction of the relay output that has been determined based on the dataset. This indicates the success of the NN in training and accurate adjustment to the dataset used. In testing the ATS with various weather conditions, variations in the use of electrical energy sources between solar panels and batteries. When the robot stays, the ATS chooses solar panels when the weather is sunny. However, when the weather is cloudy, the ATS prefers to use batteries.

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