SOLAR PHOTOVOLTAIC SYSTEM FAULT IDENTIFICATION USING ARTIFICIAL INTELLIGENCE

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DECLARATION

I declare that this thesis entitled "SOLAR PHOTOVOLTAIC SYSTEM FAULT IDENTIFICATION USING ARTIFICIAL INTELLIGENCE is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have checked this report entitled "SOLAR PHOTOVOLTAIC SYSTEM FAULT IDENTIFICATION USING ARTIFICIAL INTELIGENCE" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature : .....

Supervisor Name : .....

Date : .....

DEDICATIONS

To my beloved mother and father

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ABSTRACT

Solar photovoltaic system is design to generate electricity and operate reliably over the entire life of the product. Despite this, there are still failures could occur that can affect the performance of the product. Power failures could be one of the causes. The causes of fault could be from lightning, natural disaster, animal etc. The most advanced solutions, such as expert systems are related to knowledge-based systems. However, the subject field is experiencing congestion as it is unable to learn or adapt to new situations. This thesis is dedicated to implement artificial neural networks (ANNs) for fault identification at the solar photovoltaic system. ANNs is a computing system that inspired from biological neural network such as human brain and has ability to extract significant links from data presented. In principle, ANNs can remove the limitation of expert system as it has adaptive structure. Back propagation neural network (BPNN) was used in this project as it has simplest form but effective. Supervised learning is the training method that been used. The results from this thesis demonstrate that BPNN have high accuracy and give good performance in fault identification at solar photovoltaic system.

ABSTRAK

Sistem fotovoltaik solar adalah direka bentuk untuk menjana elektrik dan beroperasi dengan baik sepanjang hayat produk. Walaupun begitu, terdapat kegagalan yang boleh berlaku seterusnya menjejaskan prestasi produk. Kegagalan kuasa boleh menjadi salah satu punca tersebut. Punca-punca kesalahan boleh diakibatkan dari petir, bencana alam, haiwan dan sebagainya. Penyelesaian yang paling maju, seperti sistem pakar adalah berkaitan dengan sistem berasaskan pengetahuan. Bagaimanapun, bidang pelajaran dalam kawasan ini sedang mengalami kesusahan kerana ia tiada keupayaan untuk belajar atau menyesuaikan diri dengan situasi baru. Tesis ini didedikasikan untuk melaksanakan artificial neural networks (ANNs) untuk mengenalpasti kesalahan pada sistem fotovoltaik solar. ANNs adalah sistem pengkomputeran yang diilhamkan daripada rangkaian neural biologi seperti otak manusia dan mempunyai keupayaan untuk mengekstrak hubungan penting dari data yang dikemukakan. Pada dasarnya, ANNs boleh menghapuskan batasan sistem pakar kerana ia mempunyai struktur penyesuaian. Back propagation neural network (BPNN) digunakan dalam projek ini kerana ia mempunyai bentuk yang paling mudah tetapi berkesan. Pembelajaran yang diselia adalah teknik latihan yang digunakan. Hasil dari tesis ini menunjukkan bahwa BPNN mempunyai ketepatan yang tinggi dan memberikan prestasi yang baik dalam mengenal pasti masalah pada sistem fotovoltaik solar.

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LIST OF SYMBOLS AND ABBREVIATIONS

ANN	-	Artificial neural network
PV	-	Photovoltaic
BPNN	-	Back propagation neural network
DC	-	Direct current
AC	-	Alternating current
w	-	Weight
MLP	-	Multilayer perceptron
i	-	Nodes in input layer
j	-	Nodes in hidden layer
k	-	Nodes in output layer
t	-	Target output
n	-	Step of iteration
η	-	Momentum term
MPPT	-	Max power point tracking error
nntool	-	Neural network tool
FYP	-	Final year project
traingdx	-	Gradient Descent backpropagation algorithm with adaptive learning
learngdm	-	Gradient descent with momentum weight/bias learning
MSE	-	Mean squared error
epoch	-	Iteration
MCB	-	Miniature circuit breaker
R	-	Regression
L1	-	Line 1
L2	-	Line 2
L3	-	Line 3
E_p	-	The averaged sum squared error
α	-	Learning parameter
I_k	-	The input for output layer
δ	-	The error signal
Φ		Transfer function
t_{pk}		The expected output value kth output node
y_{pk}		The real output value of kth output node

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Artificial neural networks (ANN) was a main tool that work as machine learning for the purposes of acquiring and storing knowledge. ANNs work as a brain system that have ability to learn system behaviors during a training process. The capable of ANN in making future generalization by fact that the algorithm can be subjected to previously unseen data and provide system performance predictions by provide realistic output for input not encountered during training. Generally, the application of these technologies was more focus on complex signal processing and pattern recognition. however, these technologies established before the technologies of computer dawn, and has survived for a long period.

The history of neural networks has been divided in four stages and that are beginning of neural networks, first golden age, quiet years and renewed enthusiasm which shows the interplay among biological experimentation, modelling and computer simulation, hardware implementation [1]. The first person who attempt to established models of neural network are McCulloh and Pitts in 1943. The ideas were about what can a simple neural network could do in term of principle and computing any arithmetic or logical function. The McCulloh-Pitts neuron models is simple yet has significant computing potential. This model can only generate a binary output with the fixed value of threshold and the weight. The beginning of neural network occurs between 1940s to 1950s. A lot of works were attempts during those years to improve the neural network systems.

The first golden age of neural networks happened between 1950s to 1960s. The idea of using perceptron neural was invented by Frank Rosenblatt, Charles Wightman, and others between 1957s and 1958s. Perceptron neural was updated in term of weight, deciding and reacting based on the threshold. Today, Frank Rosenblatt was known as the founder of Neurocomputing. Slightly later, Bernard Widrow working with his

graduate students in developed a different type of neural network processing element called ADALINE. This neural network was equipped with a powerful new learning law which, unlike the perceptron leaning law, is still in wide- spread use [1]. Before the era of quiet years started, back propagation was proposed by others researcher in 1963s. Back propagation does not have feedback connection, but the errors are propagated during training.

In the quiet years during 1970s, A great deal of neural network research went on under the headings of adaptive signal processing, pattern recognition, and bio-logical modelling [1]. Many of the researcher were began to publish their work during those year. In those years, Paul Werbos has developed the basic idea around 1974 about the backpropagation algorithm for his thesis at Harvard University that was rediscovered in 1986 by Rumelhart and has a lot of importance nowadays [2].

The last stage was about renewed enthusiasm that occurs in 1980s. In those year, many of researchers were brave enough to propose and submit the neural network development. In the years of 1983s to 1986s John Hopfield, an established physicist of worldwide reputation, had become interested in neural networks a few years earlier [1]. The papers that has been established by John Hopfield and then have persuade hundreds of highly qualified scientist, mathematician and technologies to join the emerging field of neural network. By time passing, back propagation had made a comeback improvement in term of using multi hidden layer and this have led this network to gained recognition. Multi-layered perceptron or back propagation have advantages in solving nonlinearly separable problems, big computation, local optima and overfitting.

1.2 Motivation

Nowadays, power generation based on solar photovoltaic sources has increase progressively during the last few decades [3]. Solar photovoltaic has played a key role in evolution of the electricity factor [4]. The development of solar photovoltaic has increase due to the efficiency of itself. This statement was proof by with the recent record 44.7% of efficiency by the maximum attainable output power that been absorb from the sun energy [3], [5]. Although the solar photovoltaic has become a great technology for power generation, the harm of this technology will still give effect to humanity.

Solar photovoltaic is an electrical power system that cannot run from problem when fault occur. Fault is abnormal current that flow from the source to the load. A fault in electrical system usually a big problem that can give a threat to the continuity of electrical supply [6]. As the fault occurs in solar photovoltaic, it will give a harmful damage to the solar panel or the load. In power plants, fault can normally occur due to various type of cases such as lightning, equipment damage or natural disaster [6]. Furthermore, a heavy current can cause the cable to melt and this will lead the equipment on fire [4].

In a nutshell, a fault detection is needed in solar photovoltaic panel to avoid the harmful to effect humanity. This will be a further step before the fault problem become even serious. Moreover, this will lead an opportunity to engineer or technician in helping of detecting the fault.

1.3 Problem statement

In electrical system, fault is common things that happen when the equipment is too old or because of some other cases such as lightning and equipment damage. In solar photovoltaic system, fault can occur if there is lack of supervision for the system mechanism. The problem when using solar PV for generation side is its PV system need to be supervised by technician or engineer that proficient with the system. To overcome this problem, performing back propagation model of neural network (BPNN) will lead in helping to supervise the solar photovoltaic system. Several types of fault would happen in solar photovoltaic such as line to line fault, ground fault, open and short-circuited fault and mix match fault [7]. These faults will degrade the performance of solar photovoltaic system and decrease the output power.

Moreover, performing a manual checking may give harm to the technician or engineer because of less accuracy in determined the fault and it is potentially dangerous since the solar photovoltaic system that may run at large voltage and current. Among of those faults, line to line and ground fault are the most common fault in solar photovoltaic system but it is hard to be detected [7]. In order to avoid manual checking, fault detection in solar photovoltaic is needed so that it can verify what type of fault happen and make the things easier for the technician or engineer.

Furthermore, this project is about detecting fault by reading the value of abnormal voltage and abnormal current. Potential problem may occur at direct current

(DC) side of the solar PV when reading was taken. Bridging fault or shading are some example of potential problem. As the fault occur, back propagation neural network (BPNN) will showing the result. BPNN need to be trained many times so the approximate value of fault can be determined. BPNN is a feed forward control (FFC), so the output of voltage or current itself need to be trained again so it can learn in detecting the voltage that not suitable for the solar photovoltaic. The training may take some time and need to be repeated many times, but the process will give an advantage in getting the fault.

1.4 Objective

1. To implement fault detection in solar photovoltaic using back propagation neural network (BPNN).
2. To analyses the systems accuracy and performance in detecting fault at solar photovoltaic.

1.5 Scope of Project

The back propagation neural network (BPNN) technique is used to analyses the fault detection in solar photovoltaic. The software that used in performing simulation for back propagational neural network (BPNN) is MATLAB. Next, the types of fault may occur at solar photovoltaic are DC and AC sides fault based on line 1, 2 and 3. Solar photovoltaic at FKE UTeM Plus SW 255 (mono) has been used in this project to collect the fault data. Moreover, Types of input in BPNN for training and testing is current while the output is power. Lastly, the data for both DC and AC side fault were collect from 10.00 am to 3.00 pm.

CHAPTER 2

LITERATURE REVIEW

2.1 Biological Neural Network

Past few decades, the study on the construction and operation of our brain and nervous system have given a lot of benefit for operation system. The basic building block of the nervous system is the neuron. Neuron consist of cell body, dendrites and an axon as shown in Figure 2.1. Neural network architectures are based on the human brain and nerve cells. The signal flow in neuron goes from the dendrites, through the cell body and out through the axon.

The nucleus is the main part of a neuron that connected to the other part neuron body to form neuron network. The connection of the nucleuses is made by dendrites and axon that was called synaptic connection. The impulses can be pass through other neuron by using synapses which are located on the dendrites. The neuron is activated when the signals received surpass a certain threshold [8]. The output area of the neuron is a long branch that called axon and the dendrites will be the input. When a series impulse received by the dendrites, the neuron will be activated and emit impulse through the axon.

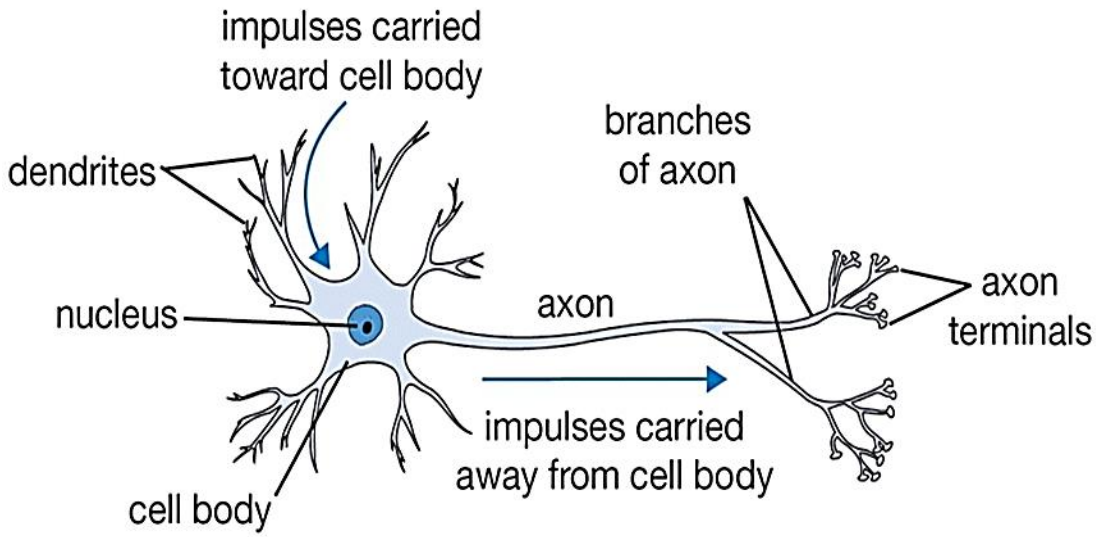

Figure 2.1 Biological Neuron [9]

2.2 Artificial Neural Networks Basic Structure

In ANNs structure, weight refers to the strength or amplitude that connected between two of nodes. Figure 2.2 shows schematic processing units for ANNs. The multiple of input are connected to the unit shown at the center. Each connection has its own strength, given $w_1, w_2, \ldots, w_n$. When the process begins, the units of the network will perform a weighted sum on the inputs and uses a nonlinear threshold function, f, to compute its output. The calculated result then will be emitted to each of the output connections.

The ANNs consists of three main part body which is input, hidden and output layer. Figure 2.3 shows an ANNs with three connected layers. The input layer brings the initial data into the system for further processing by artificial neuron subsequent layer. By getting the input is the first step in artificial neural network workflow. The hidden layer take place between input and output layer and consist of features detector unit that respond to particular features that appear at input layer. The output of the hidden layer will be generated via activation function. Output layer is the last layer in ANNs structure. It read as the output the network. This unit will collect the information and transmit it accordingly.

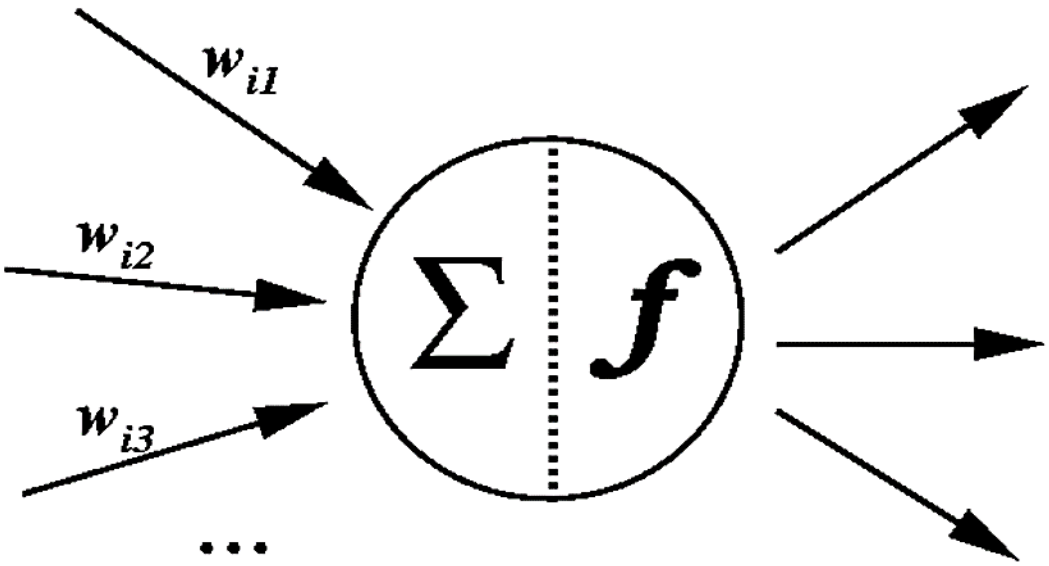

Figure 2.2 Schematic Processing Unit of ANNs [9]

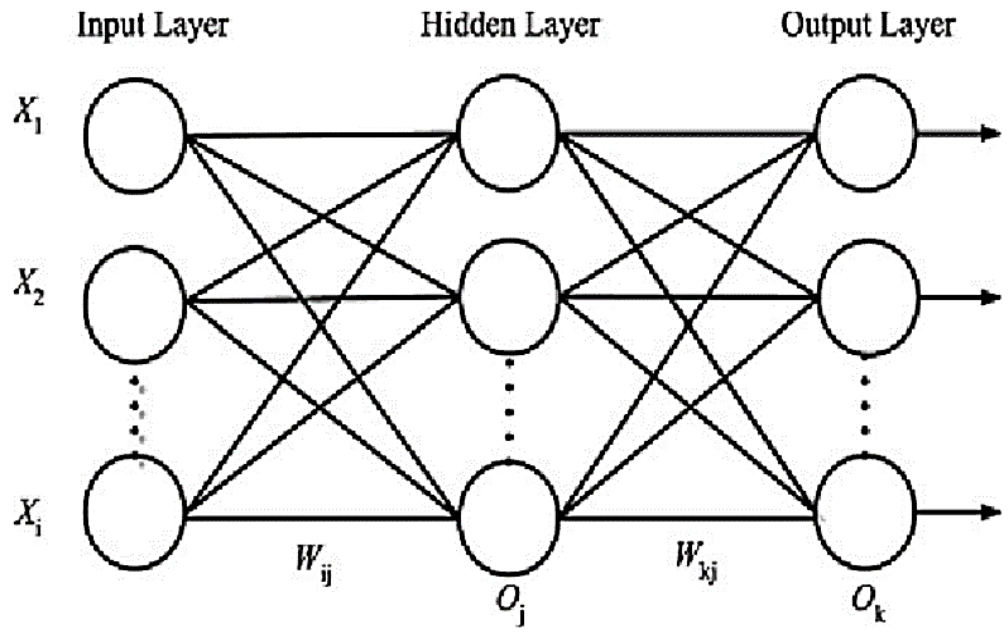

Figure 2.3 ANNs With Three Connected Layers [9]

2.3 Characteristics of ANNs

A neural network is massively parallel distributed processor that made up with simple processing unit that has natural tendency for storing knowledge and making it available for use. ANNs characteristics need to be consider before utilizing them for solving practical problem such as fault identification in solar PV.

2.3.1 Mapping capabilities

ANNs can be considered as black box as it can transform the input vectors x from an n-dimensial space to an output vector y in m-dimensial space $F : x \rightarrow y$. By using a proper and absolute ANNs architecture, the types of mappings can be approximately known. Mapping problems can occur when there are no restrictions such as linear separability is placed on the input-output pattern pairs.

2.3.2 Learning and generalization

Learning in ANNs consist of supervised, reinforcement and unsupervised. Supervised learning uses a training set consist of input pattern and output pattern as

the target value. The output may regard as network teachers to the input. This network leaning need to compute the output for the current network weight and adjust the weight so that it can minimize the difference between the actual output with desired output. Reinforcement learning uses less of supervision and its signal is simple as yes or no at end of the given task to indicate whether the task is done with satisfactorily. Last, unsupervised learning only use input data and there is no training signal. This learning only needs to proof the data set true or not, for example grouping the same pattern.

Generalization regarding the Artificial Neural Network (ANN) is defined as the network's ability to deal with unseen patterns [10]. Generalization can serve as efficient mode of memorization and storage. By having generalization, a lot of details that human brain cannot store can be identified, learned and stored at neural networks such as unlimited number of specific events, facts, relationships and other details that related to human experiences. In fact, generalization is an intelligent behavior.

2.3.3 Parallel Processing

The ANNs are computer mods that try to imitate the brain's learning function [10]. Parallel processing structure has large numbers of processors and many interconnections between them. The artificial neural networks consist of a set of neurons or processing units that are connected by means of weights connection [10]. The power of the neural network lies in the enormous number of interconnections.

2.3.4 Fault Tolerance

Fault tolerance can ensure their reliability when significant portions of a network are lost [11]. Furthermore, fault tolerance can ensure the fidelity and reality of the relationship between input and output of the system. Fault tolerance is to verify that the presence of errors can be overcome by changing the variable parameters in the network such as the synaptic weight of the network [12].

2.4 Back Propagation Neural Network (BPNN)

2.4.1 Overview

Usually, neural network needs to be trained or adjusted so that a particular of input can lead to a targeted output. BPNN need to be trained many times so the approximate value of output can be determined. Neural network was trained like a human brain that consist of input, weight (hidden layer) and output. BPNN undergoes supervised training with a lot number of patterns. The number of neurons in input layer determines the dimensions of the input and the number of neurons in output layers determined the dimensions of the outputs.

Furthermore, the weights are been adjust based on the comparison of the output and the target until the network output match the target value [13]. This hidden layer output is determined by using a threshold function with the activations of the input. Next, the activation of the hidden layer than will become the input for the target output. Figure 2.4 shows the line diagram of working BPNN.

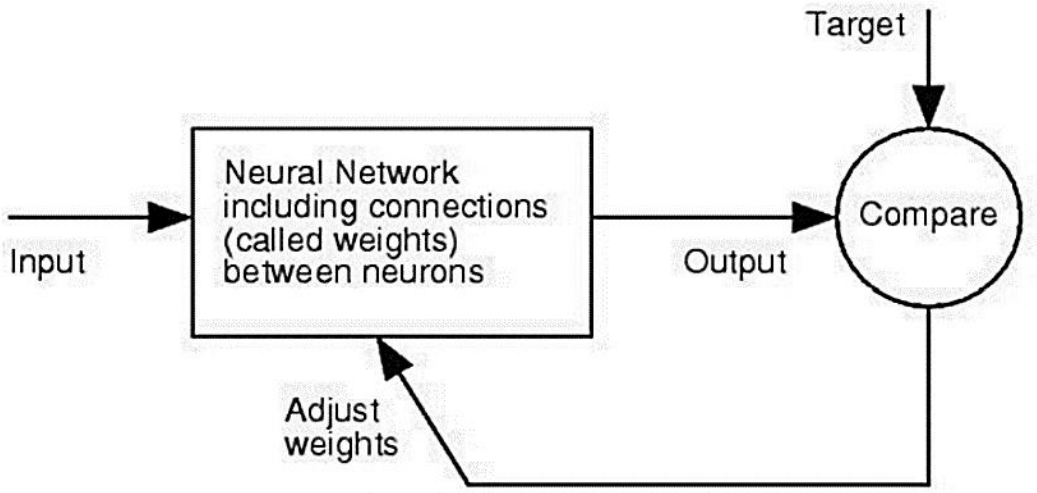

Figure 2.4 Line Diagram of BPNN [13]

BP neural network was the first and simplest type of artificial neural network this day. The information only moves in one flow in this neural network. BPNN does not have feedback connections, but the errors are back propagated during training. This is because BPNN can only flow in forward direction. BPNN also work as normal neural network that consist of input for the data collection, hidden layer for the data