# DETECTION AND CLASSIFICATION OF DEFECTS IN A PHOTOVOLTAIC SYSTEM USING THE NEURONAL APPROACH

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***Abstract***-Nowadays, Photovoltaic has quickly become one of the most important renewable energy technologies; this energy is widely used in a number of applications due to its advantages, including non-polluting energy. During its functioning, a photovoltaic system can be submitted to various defects, which require a certain approach to detect them for restoring the system to a normal state. There are several techniques and methods for the diagnostic of a photovoltaic system. In this work, we were specifically interested in the detection and the localization of the defects of the photovoltaic module using artificial neural networks, these networks are an important branch in the field of artificial intelligence, they are based on the establishment of learning algorithms that allow finding the best solution to some problems, a general overview of the neural network and their characteristics are discussed, then a multilayer perceptron MLP network is made to detect and classify some defects of a photovoltaic module.
***Keywords***— Photovoltaic System, Diagnostic of Systems, Detection and Classification of Defects, Artificial Neural Networks ANNs, Learning Algorithm

## 1. Introduction

A photovoltaic system composed of an arrangement of several components, in the relation between them. The basic element of the system is the photovoltaic generator (PVG), it consists of elementary photovoltaic modules associated in topology, and other equipment as the protection elements, batteries, the cabling, the junction box and the power converter. During its functioning, the generator can be subjected to various defects and anomalies leading to a reduction in the performance of the system, thus reducing the productivity of the installation and its quality, without counting the costs of maintenance to restore the system to a normal state [1, 2].

To ensure the smooth running of the photovoltaic system, it is necessary to treat these various defects, through diagnostic methods. Seen the complexity of the classical methods and its limitations, there are techniques that are a part of emergent methods as the networks of artificial neurons. The neural network approach has proved its effectiveness in several areas, as information treatment [3], faults classification of induction motor [4], fault Detection of gearbox [5], health diagnosis [6].

The neural networks used in artificial intelligence to imitate the human intelligence and copy this ability to the machine, the most popular search engine in the world does not miss the opportunity to integrate neural network technology into their products, Google uses this technology in google image to identify similar images to the one that we provide (left-click on a chosen image and drag-drop it into the search angle) and see the similar images. It is important to note that neural networks have advantages and disadvantages, among the advantages: the neural networks can treat incomplete or noisy data, the ability to represent any complex function, and the ability of learning based on examples. Among the disadvantages: there is no definite method or rule to determine the best architecture of the neural network (number of hidden layers, number of neurons in each hidden layer).

Our objective is used neural networks for the diagnosis of a photovoltaic generator. This paper is organized as follows: In Section 2 a general overview of the neural networks and their characteristics are discussed, in Section 3 the application of the method of neural approach for a photovoltaic module

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diagnosis is presented, and results obtained are given in Section 4, before concluding the work with conclusion in the last Section 5.

## 2. Method of neural networks

The human being can predict, identify and classify the data, for example, we take a child of 10 years old and present him a set of images, hecan easily differentiate animal images, object images like a circle, a square, a triangle. This task is very simple for human beings but it is difficult for machines even supercomputers, from here researchers begin their search to imitate human intelligence and copy this ability to the machine.The artificial neural networks ANNs are an important component in the field of artificial intelligence. They are proved them efficiencies in several applications, There are many applications that use artificial neural networks such as the function approximation, trajectory optimization, pattern recognition and classification [7] [8] [9].

### 2.1.The architecture of a formal neuron

Each artificial neuron is an elementary calculation unit. He calculates a single output on the basis of the information which it receives. With each one of these inputs, it is associated a weight. The artificial neuron makes a weighted sum of the outputs from other neurons and then this sum is subjected to a nonlinear transfer function [8] [10].

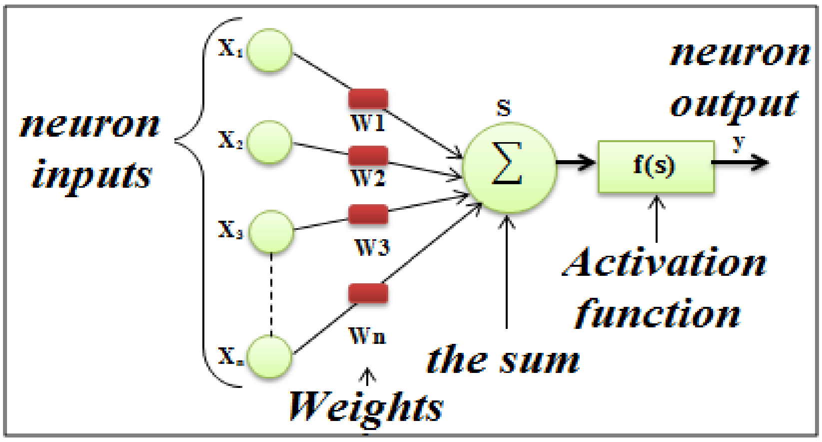


*Figure 1 Model of an artificial neuron.*

The neuron behaviour is governed by the following equations:

$$S = X_1W_1 + X_2W_2 + \dots + X_nW_n = \sum_{i=1}^{n} X_iW_i \tag{1}$$

$$Y = f(s) \tag{2}$$

$X_1, X_2, \dots, X_n$: The neuron inputs.
$W_1, W_2, \dots, W_n$: The synoptic weights that control the passage rate of the input signals.
S: The weighted sum.
Y: The neuron output.
f: The transfer function.

The commonly used transfer functions for training neural networks are presented in Table I. The log-sigmoid transfer function is the most used in multilayer networks with the back-propagation algorithm

*Table 1 The transfer functions*

| Name | Input/output Relation |
|---|---|
| Hard Limit | $f(x) = \begin{cases} 1 & x \geq 0 \\ 0 & x < 0 \end{cases}$ |
| Symmetrical Hard Limit | $f(x) = \begin{cases} 1 & x \geq 0 \\ -1 & x < 0 \end{cases}$ |
| Linear | $Y = X$ |
| Log-sigmoid | $Y = \frac{1}{1 + e^{-x}}$ |
| Hyperbolic tangent | $Y = \frac{e^{x} - e^{-x}}{e^{x} + e^{-x}}$ |

## 2.2.Learning of the neural networks

The learning of a neural network is the phase of development of this network until the obtaining of the desired behaviour. The weights of connections are adjusted several times before reaching their final value. The algorithm of learning is presented (see Figure 2).At the beginning the weights are randomly initialized, we present the inputs to the network for calculating the output, from these result and the desired outputs the error is calculated and the correction of the weights will be applied if the objective is not achieved.

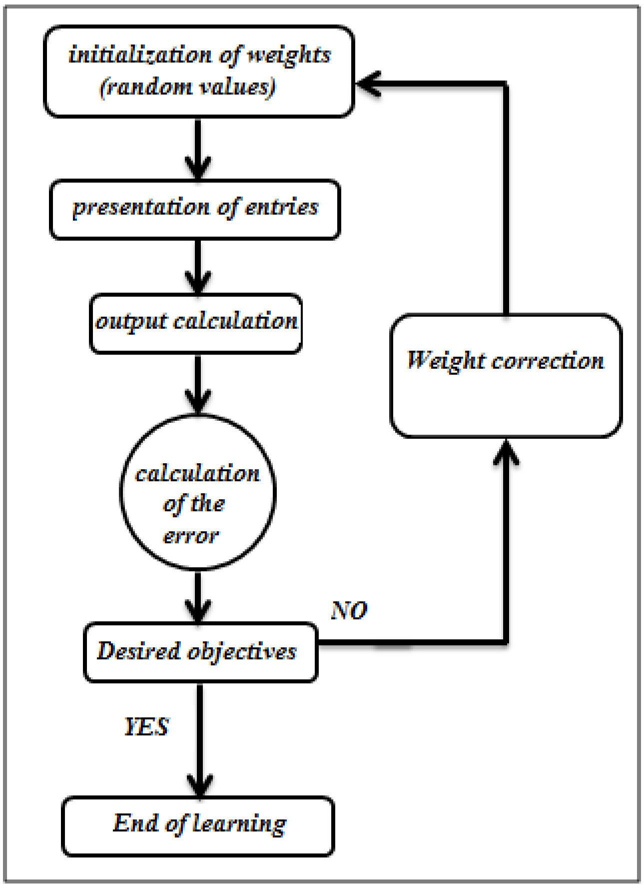


*Figure 2 The learning algorithm of a neural network.*

All neural networks have the same learning procedure which consists of four steps:
Step 1: Initialization of weights with random values.
Step 2: Presentation of the inputs and calculation of the corresponding outputs.
Step 3: Error calculation between outputs.
Step 4: Correction of weights according to the calculated errors.
The steps 2,3 and 4 are repeated until the end of the learning process.

## 2.3.Application of the neural networks for photovoltaic module diagnosis

The photovoltaic module is characterized by the P-V and I-V characteristic curves, therefore by the processing of these signals a several information can be collected, the first step is the construction of a normal photovoltaic model and used as a reference model, then generate some defects on another healthy photovoltaic module of the same type and extract the informations of anomalies. The principle is to calculate and compare the measurement errors between the normal photovoltaic module model and the module to be diagnosed. The second step consists of calculating the maximum voltage error ($e_v$), the maximum current error ($e_i$), and the maximum power error ($e_p$) to generate a database for used by the neural approach. For the diagnostic of the photovoltaic module, four defects are chosen to apply the method of neural networks. Table II includes a description of each defect.

*Table 2 Description of the defects*

| Defect number | Description |
|---|---|
| Defect 1 | Mismatch faults with the variation of the value of series resistors.The defect of “Rs” is the result of the male connectivity and fissures in the photovoltaic cells. |
| Defect 2 | A decrease inthe number of cells in the PV module,this defect affects the characteristics of the PV module. |
| Defect 3 | Photovoltaic Module shunted. |
| Defect 4 | Partial shading fault, this fault can generate by the variation of the photocurrent Iph. |

The neural network development process has four steps [9-11]:

### 2.4.The generation of residues

For the generation of residues we compare the normal PV module and the system with defects, and then calculate the maximal and means values of the errors of the current, voltage and power, for this application we have to choose 4 defects such as 30 measures for each, therefore 120 samples were considered.

### 2.5.Data collection

The collection of measurements is made using a file, to realize the database that contains the necessary information of each defect. It allows us to classify them.

### 2.6.Neural network architecture

The construction of the Neural networks with the configuration of the input layer, the hidden layer and the output layer, also the activation function and the learning algorithm.The neural network is an MLP network (06-20-04), 06 neurones in the input layer, 20 neurons in the hidden layer and 4 neurons in the output layer. The "Hyperbolic tangent" transfer function is used for the hidden layer and the "linear function" for the output layer. The learning algorithm used is the "back-propagation algorithm".

### 2.7.Learning of the neural network

For the learning, we used the database of 120 samples collected,the mean and the maximum of the errors of current, voltage and power as inputs. The desired output in which a binary coding has been chosen: [1000] for "DEFECT 1", [0100] for "DEFECT 2", [0010] for "DEFECT 3", [0001] for "DEFECT 4".The database will be devised to train the neural network and the test.

## 3. Results and discussions

The technique of neural networks used for the classification of defects. The neural network development process involves the following steps: the generation of residues, data collection, neural network architecture, and learning the neural network. Figure.3 shows the learning block of the MATLAB software network.

The following table shows the classification percentages of the four defects by the neural networks for 1000 and 40000 iterations.

*Table 3 The percentage of the defects classification*

| | *1000 iterations* | *40000 iterations* |
|---|---|---|
| *Total Percentage* | 81.6667 | 96.6667 |
| Percentage “DEFECT 1” | 93.3333 | 100 |
| Percentage “DEFECT 2” | 86.6667 | 100 |
| Percentage “DEFECT 3” | 86.6667 | 93.3333 |
| Percentage “DEFECT 4” | 60 | 93.3333 |

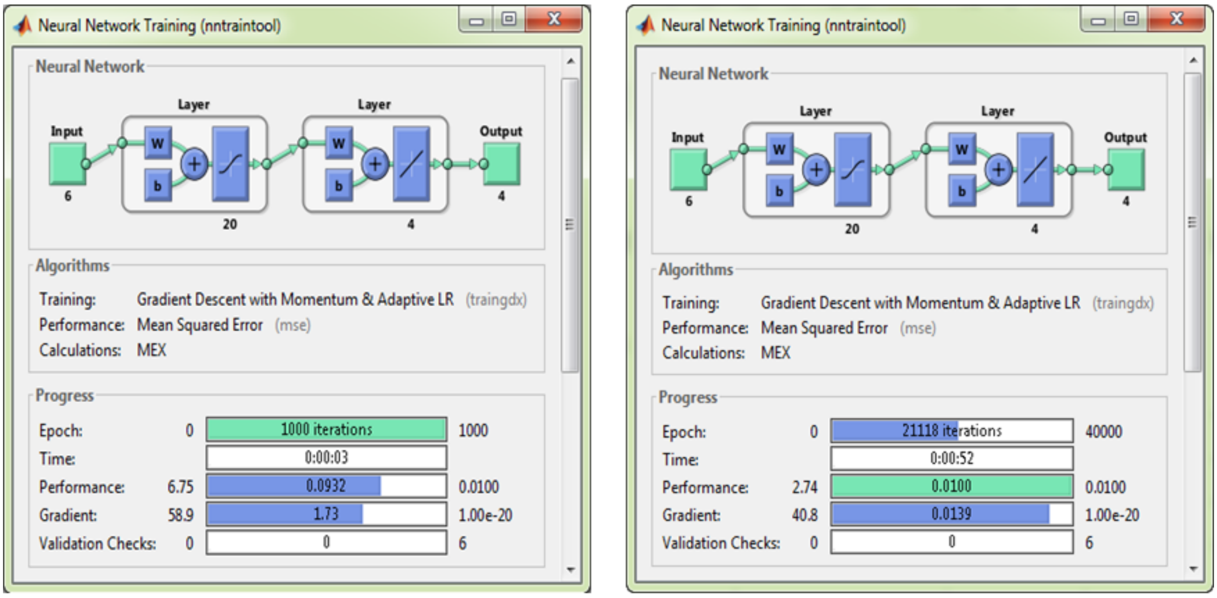


*Figure 3 MATLAB learning block of the neural network with 1000 iterations (left) and 40000 iterations (right)*

The applied network of neurons achieves the final goal, which is the classification of four defects and shows at the same time the percentage, which allows us to judge its functioning.

It is noted that the desired maximum error (0.01) is not achieved with 1000 iterations, to achieve the quadratic error in the learning phase of the neural network with the performance function (Goal= 0.01) it is necessary to change the number of iterations until the performance is quite good, we notice that the maximum desired error is achieved for a number of iterations equal to 21118 without doing all the selected iterations (40000 iterations).From the obtained results, it can be said that the neural approach is based on a database to classify defects and it is a very simple technique. You don't need complex programming languages just build and run the network.

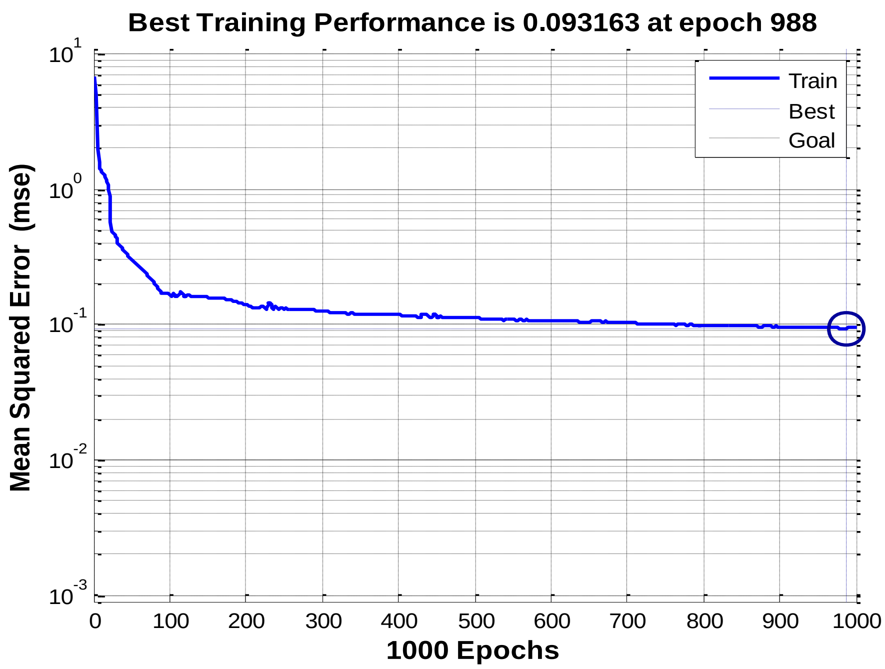


*Figure 4 The quadratic error with 1000 iterations.*


*Figure 5 The quadratic error with 40000 iterations.*

## 4. Conclusion

In this work, the detection and classification of defects in a photovoltaic module using the neural approach is presented. The objective is to develop a program for automating data classification using multilayer perceptron (MLP) neural networks. The data considered are selected defects of a photovoltaic module, after having worked with neural networks for the diagnosis of a photovoltaic system several secrets of artificial intelligence are discovered. The made processing is not interpretable because the neural networks are considered as black boxes in which internal information is encoded by weights and is unknown by the user, if the user needs to be able to interpret the obtained results, it will choose another method.

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