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Artificial neural network-based modelling and fault detection of partial shaded photovoltaic modules

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ABSTRACT

In this paper, a fault detection method for photovoltaic module under partially shaded conditions is introduced. It consists to use an artificial neural network in order to estimate the output photovoltaic current and voltage under variable working conditions. The measured data (solar irradiance, cell temperature, photovoltaic current and voltage) at Renewable Energy Laboratory REL, Jijel University (Algeria), have been used. The comparison between the estimated current and voltage with the ones measured gives useful information on the operating state of the considered photovoltaic module. To show the effectiveness of the proposed method, several shading patterns have been investigated. The results showed that the designed method accurately detects the shading effect on the photovoltaic module.

1. Introduction

Today, the photovoltaic (PV) industries have recognised important development in photovoltaic equipment's fabrication and the number of installations. The use of solar energy requires optimizing the efficiency of the conversion chain and to maintain the performances of PV installations. These requirements highlight the need to equip the PV installations with efficient monitoring equipment and tools [1]. This has become possible due to the cooperation of several efforts to improve the technical characteristics of the PV plants in one hand, and to develop more efficient monitoring tools and systems on the other hand [1,2]. The use of monitoring systems in the PV installation allows the optimization of their operation by obtaining indicators about their operating states. Moreover, monitoring systems and tools permit the establishment of data analysis, comparisons, identifications, fault events detection and identification [3,4]. Monitoring systems should be able to follow the operation state of the plant at all times, in order to maintain better optimal operating conditions and to allow the detection of eventual errors and failures that can be considered as factors of performances losses. In the PV installations, the PV generator is considered as the most important component. However, it is also the component that is most affected by failures. In this perspective, the PV generator should benefit from much intensified monitoring hence requires special interest.

Photovoltaic plant performances are lost through several factors affecting their generators such as shading, soiling and cells shunting [5]. To overcome the cited problems, multiple parameters need to be monitored continuously in order to promptly detect any abnormal losses and faults occurring on the PV plant. Hence, in many monitoring systems, the monitored parameters includes: temperature, solar irradiances, DC/AC current and voltage [6].

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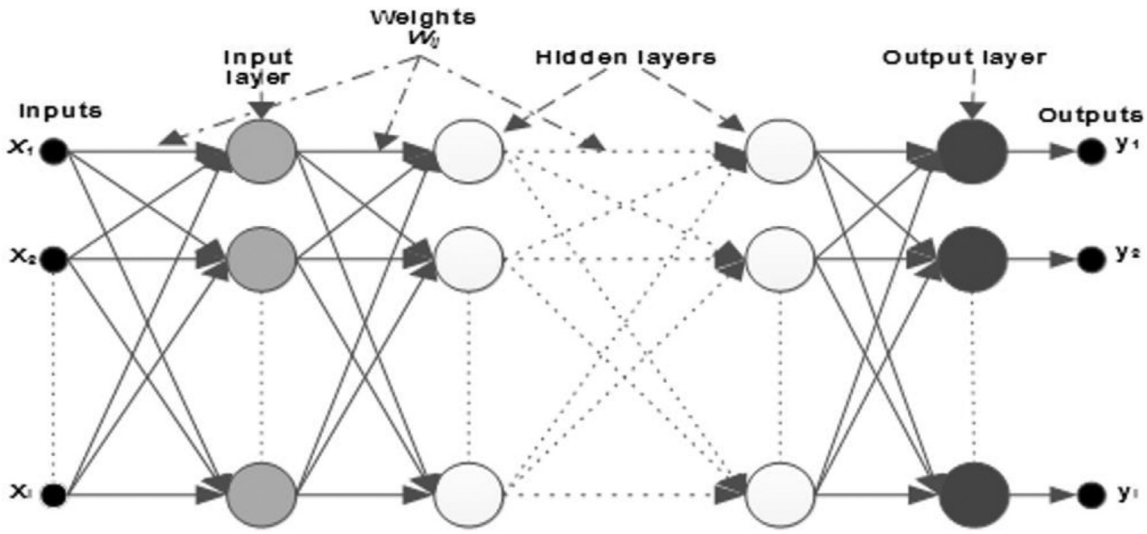

Fig. 1. The employed MLP neural network structure [34].

Several existing faults detection methods are operated only off line [7–10], as they use data collected during the functioning of plants over a given periods to analyse their operating states and to detect abnormal losses and faulty situations (e.g.: monthly, weekly,…, etc.). In addition, others methods require complex mathematical calculations in order to estimate some faulty related parameters such as temperature and series resistance of PV generators [11,12]. The majority of the available methods depend strongly on the measurements and the analysis of the system performances under its functioning state such as voltage, current, power and *I–V* curve measurement [13], which do not give in some cases the real operating state of the system (e.g. in case of partial shading). Therefore, the monitoring systems still blind to some cases of defects that require a special redundancy to be detected and identified. In addition, these methods need in many cases a complex data analysis to deduce the operation state of the PV system [14].

The partial shading is considered among the most severe faults because of the harmful effect that can produce on the PV modules [15,16]. Various methods have been investigated for the detection of this fault, these methods are often based on the analysis of electrical [17,18] and non-electrical parameters [19,20].

Artificial neural networks (ANNs) have been successfully employed in the field of photovoltaic [21], such us PV power forecasting [22,23], performances evaluation [24,25], modelling and simulation [26,27], as well as maximum power point tracking under shading conditions (MPPT) [28–32]. However, the ANNs have not yet better investigated in the field of PV systems monitoring and fault detection, although they can provide a significant improvements of monitoring systems and faults detection. A preliminary research has been carried out based on the use of ANNs for the modelling and monitoring of the photovoltaic module under shading [33].

In this work, we present an ANN based-method for online faulty state detection of PV module under partially shaded conditions. It permits the real time fault detection via the estimation of the electrical outputs (output current and voltage) of the monitored system using only two meteorological parameters (solar irradiance and cell temperature). It could also be used to detect possible anomalies occurring in the PV module by the real time correlation of the estimated performances with the one measured under variable conditions. The proposed detection method can be viewed as a redundant model which is independent of the measured PV module performances. So, this redundancy makes the system of detection autonomous, and can conclude in any case the operating state of PV module.

2. Materials and methodology

2.1. Artificial neural networks

Artificial neural networks are inspired from biological neural networks of the human brains [34]. In the implementation of artificial neural networks, knowledge is represented as numeric values called weights. Weights are used to perform the relationships between the inputs parameters and the output parameters of the physical process that are difficult to find by analytical models. The most commonly used ANN in the field of modelling and approximation is the Multilayer Perceptron (MLP) which is considered in this study. The MLP is considered to be a typical back propagation ANN and consists of an input layer, hidden layers and an output layer, as shown in the Fig. 1.The MLP is usually trained by the back propagation of errors between desired values known as targets and outputs of the network using gradient descent or conjugate gradient algorithms [34].