http://www.jctjournals.com

ISSN(ONLINE):2278 - 3814

Volume-12, Issue 02, February2023

JOURNAL OF COMPUTING TECHNOLOGIES (JCT)

International Journal

Page Number: 01-07

A Review On The PV Array Fault Diagnosis

Gunja Kumari[1], Rishabh Shukla[2]

[1]PG Scholar, [2]Assistant Professor

[1,2] Department of EX,OCT Bhopal, M.P India,

[1]Gunjakumari1401@gmail.com, [2]rishabhshukla002@gmail.com

***Abstract*— Photovoltaic (PV) systems have risen fast in the solar sector. Detecting and predicting PV system defects improves efficiency, reliability, and lifespan. PV panels work hard, which may cause several problems that damage the system's performance and lifespan if not discovered or forecast. Previous research revealed defect detecting methods. These approaches identify defects at various PV system sites. Some methods detect DC faults, whereas others detect AC faults. This document discusses frequent DC side PV system (PV panel) problems, their sources, consequences on PV performance, and diagnosis and prediction. This study will classify flaws as permanent, intermittent, or transitory and as incipient. Identifying incipient problems early may avoid irreversible defects. This review study describes main PV panel failure detection technologies and classifies them by detection and prediction methods. The study describes the best PV array failure detection methods*m*.**

***Keywords*— Photovoltaic Arrays, PV Faults, Fault Detection techniques**

I. INTRODUCTION

Over the course of the last ten years, countries all over the globe have seen a surge in the development of photovoltaic (PV) technology and systems [1]. PV is considered to be the most promising and major renewable energy source due to its ability to provide clean energy at various power levels and in various sites including domestic, due to a vast and unfailing energy, and constantly replenished energy supply [2]. This is one of the reasons why PV is considered to be the most promising and major renewable energy source. It makes a substantial contribution toward improving energy security, national income, public health, and environmental protection. Solar power has quickly emerged as one of the most desirable and, in certain situations, the most cost-effective methods for the creation of new forms of energy [3].

The operation of PV can be negatively impacted by a variety of factors, including maximum power point tracking error, environmental effects such as shading and dust or snow accumulation on the PV surface, wiring losses and ageing, and malfunction in other PV components such as the power conditioner unit and the inverter. 2010 saw the publication of a monitoring study [4] that demonstrated how defects have the potential to impact on a reduction of around 18.9% in the amount of yearly electricity produced by a PV system. As a result, it was vital to create suitable methodologies that continually monitor the current, voltage, and output power characteristics of PV systems in order to identify flaws that already existed as well as those that were emerging. In order to maximise the operational performance and dependability of the whole system, it is vital to have a detecting algorithm that can identify the existence of a defect in the PV system in a relatively short amount of time and determine the reason of that failure.

In recent years, several detection approaches have been explored in the literatures to detect and identify various faults for PV systems [16-46]. These strategies have been studied to detect and identify various faults for PV systems. This shows that there is no comprehensive fault detection approach capable of identifying all of the flaws in a PV system [5].

In the context of photovoltaic arrays, the purpose of this work is to make a contribution by discussing the many flaws and detection strategies that may occur in PV systems. On this topic, we will explore the impact that errors have on the operation of PV arrays. A discussion will be held in which several current strategies for the detection and diagnosis of problems in PV arrays will be compared with one another. In addition, an analysis of the advantages and disadvantages of the current methods of diagnosis and detection, as well as a discussion of the difficulties associated with such detection approaches, will be presented.

The following is the structure of the paper: In section 2, a concise introduction is given to the subcomponents of the PV array in order to better comprehend the behavior of the PV array in response to various kinds of defects. With the next section, "Section 3," we will discuss the many problems that might occur in PV arrays, along with the

 Copyright © 2022. JCT Publications. All Rights Reserved

ISSN(ONLINE):2278 - 3814

potential causes of those problems. In Section 4, several methods of fault detection in PV arrays are discussed for the sake of clarity. The difficulties that arise from the presence of flaws in PV arrays and the various detection techniques are discussed in section 5. Finally, section 6 gives a summary and conclusion of this study.

.

II. PHOTOVOLTAIC ARRAY AND POWER GENERATION

Photovoltaic systems may be classified according to the amount of electricity they produce, the layout of the system, or the degree to which it is connected to the utility grid. The photovoltaic array, the power conditioner, the storage system, and the PV inverter are the four components that make up a typical PV system. After that, the system is either linked to a local load or it is connected to the utility grid. [6] PV modules are created when solar cells are connected together in a series configuration. This allows solar energy to be converted into electric power. PV modules may be connected in series or in parallel with one another to create a PV array that is proportional to the required amount of electric power. The primary components of the PV system are shown in figure 1.

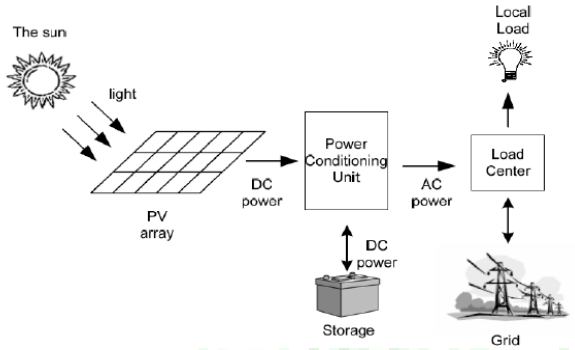

Fig. 1: Photovoltaic System Components

Figure 2 illustrates the non-linear V-I and P-V characteristics that are present in a photovoltaic module. The graphs illustrate the three significant points: the open-circuit voltage (Voc), the maximum power point (Isc), and the short-circuit current (Isc) (MPP). The Maximum Power Point Tracking (MPPT) improves the system's ability to function at the highest conceivable levels of the power that the module can give. The electrical performance of a solar cell underpins not only the V-I curve but also the P-V curve.

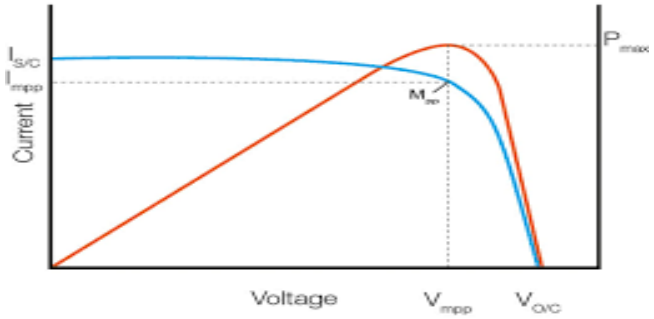

Fig. 3: I-V Curve of a PVmodule

The analogous circuit for a single diode consists of a current source that injects photocurrent Iph, a single diode that represents the phenomena of diffusion by Id, and a shunt resistance Rsh that limits the current Ish that is induced by a manufacturing flaw in the construction of a solar cell. The amount of heat that is produced by the solar cell, which is represented by the series resistance Rs, causes a decrease in the cell's overall efficiency.

III. FAULTS IN PHOTOVOLTAIC ARRAYS

With the next part, we will discuss the most common problems that might occur in solar arrays. When there is a difference between the actual and expected levels of output power from the PV array, this indicates that there is a problem. It might be because of a problem with a PV module or a string of PV modules, such as shadowing, the soiling effect and snow coverage, deterioration and corrosion, or a failed by-pass or shunted diode. In general, defects in photovoltaic arrays may be categorised as permanent, incipient, or intermittent depending on the temporal characteristic of the fault. The faults that have a transient impact, such as shade, leaves, bird droppings, and environmental stresses such as dust, pollution, snow buildup, and excessive humidity, are referred to as the intermittent faults. Permanent faults include PV module(s) damages such as short circuit, open-circuit, junction box faults, and connector damage. While incipient faults arise owing to cellular deterioration, corrosion, and partial destruction in interconnections. Incipient flaws may develop to irreversible defects.

A. Degradation in PVArray:

Degradation might be responsible for a decrease in power generation that is as high as fifty percent [8]. The outcomes of a research study that can be found in [7] suggest that the destruction of cells might be brought on by a wide number of different events. The majority of the issue may be traced back to a buildup of sticky substance that has formed between the glass and the cells. As the colour of the material changes from white to yellow and then sometimes to brown, the amount of light that is able to reach the solar cells is less. This is because the colour of the material initially started off as white. Because of this, there will be a drop in the total quantity of power generated. The second reason is known as "delamination," and it is characterized by the appearance of gaps between the different consecutive layers of the PV module. This presence of spaces shows that the adhesion between the layers has been lost.

B. Soiling and ShadingFaults:

The accumulation of snow, dust, dirt, or any other particles on the front surface of a PV module might cause it to develop a soiling defect. Hard shading faults, on the other hand, arise when photovoltaic panels are shadowed by surrounding buildings or other objects. Both of these defects lower the output voltage, which in turn decreases the amount of electricity that can be generated by the PV

Copyright © 2022. JCT Publications. All Rights Reserved

arrays. It is possible for soiling or solid shading to produce a drop in power output of anywhere from 10% to 70% [10].

C. Partial Shading Fault:

A further flaw is the partial shadowing, which results in a reduction in output power since it covers a portion of the PV array [11]. There is a possibility that clouds, smoke, dust, or other transient effects may cause partial shade to appear. The findings of an experimental study [12] have shown that shading circumstances are responsible for triggering the bypass diodes. This has an influence on the output current, which in turn leads in the presentation of a high frequency noisy I-V curve, which in turn affects the power output. It has been determined that darkened cells behave as resistance, leading to the formation of hot spots in the network.

D. Line-to-LineFault:

High fault current or direct current (DC) arcs must exist between two separate potential points in the PV array for there to be a line-to-line fault [13]. Accidental short-circuiting between two separate potential points in an array is the definition of this kind of malfunction. It is possible for it to happen between modules that belong to the same string as well as between strings that are next to one another. In addition, a line-to-line fault may happen between array cables that are at different potentials, although this kind of failure does not include any grounded points. When a line-to-line fault occurs between two modules of the same order coming from two distinct strings, it is often referred to as a bridging fault. This is because it bridges the gap between the two strings. The defect results in a drop in the voltage across the open circuit, although the current through the short circuit could remain the same. A change in the V-I characteristics of the PV array is going to occur as a direct consequence of the drop in voltage.

E. Bypass DiodeFault:

Within the photovoltaic module, the bypass diodes are installed in parallel with a certain number of solar cells. These bypass diodes stop the reverse bias heating phenomenon that may occur in solar cells when they are in a shaded environment. If the bypass diodes in solar cells are disconnected, then the heat in the cells will build to high levels, which may generate hotspots, which can lead to browning, burn marks, and fire in the worst case scenario. The V-I and P-V characteristics of a PV module are perturbed throughout the shading process, and when bypass diodes are unplugged, which also results in a large reduction in the open-circuit voltage and maximum power output of the array.

F. Open-CircuitFault:

When one or more PV strings have issues with disconnection, a defect of this kind is generated. The majority of the difficulties with disconnection are attributable to improper soldering in the interconnections between the threads. Because of the open-circuit defect, the current via the short circuit and the maximum power are both reduced, but the open voltage remains quite near to its typical value [14].

G. Earth or GroundingFaults:

A ground fault occurs when there is an unanticipated short-circuited path that involves one or more currying current conductors and the ground. This would result in a significant increase in the current that was flowing through the affected conductors, which in turn would cause mismatched currents and changes in the PV array configuration. This is what is known as a ground fault. The ensuing fault currents, disturbed or dropped output voltage, and rapid changes in the V-I characteristics of the PV array are the effects of ground fault [15]. In the photovoltaic system, ground faults are regarded to be the most prevalent kind of defect. These issues might be caused by the breakdown or failure of cable insulation, which could be the result of manufacturing errors, overheating, or old cables. A ground fault may lead to a variety of risks, including the potential for electric shocks and fire threats.

H. ArcFault:

An electrical arc defect may be caused by any intermittent connection, including soldered joints. Additionally, the breakdown of insulation on current-carrying conductors causes arcs to form between neighbouring conductors. These arcs generate high-frequency noise in the output current or voltage of a string or multiple strings, which would also result in sudden drops in output voltage and current. It is important to point out that these kinds of defects might potentially start a fire in the PV panels. [1]

IV. FAULTS DETECTION METHODS

The PV fault detection methods, in general, make it possible to determine the nature of various PV system breakdowns as well as their specific locations. These procedures need to be reliable in order to extend the lifespan of the system, boost its dependability, and ensure safe operation. In order to minimize repercussions and more failures, the strategies also need to have a quick detection rate for defects that are developing. Visual methods, image solutions, electrical methods, machine learning approaches, electric protection devices, and ARC fault detectors are the six primary categories into which the techniques may be organized. These procedures are outlined in further detail below.

A. VisualMethod:

In order to identify flaws in photovoltaic modules already installed in the field, frequent visual examinations are often carried out. They are the initial stage in determining if more tests need to be conducted to discover whether there are mechanical or electrical defects. [16] With funding from the United States Department of Energy and assistance from the National Renewable Energy Laboratory (NREL/IEA), a checklist for the visual assessment of deployed PV modules was established. The visual examination that is performed must be carried out at 1000 lux and from a variety of angles in order to prevent reflections, as stipulated by the requirements of IEC-61215. Using this technique, it is possible to identify a variety of

 Copyright © 2022. JCT Publications. All Rights Reserved

different kinds of flaws, including discoloration, bubbles, delamination, burning marks, browning, cracked glass or cells, dirt points, loose or exposed to damage wiring, interconnections rust or corrosion, snail tails, and damaged or breakage pieces. The fact that the visual assessment of PV cells relies on human skills is the process's most significant limitation. This duty has the potential to be monotonous at times and unreliable, since it may take a significant amount of time to identify a problem.

A. ImagingSolutions

ThermalMethods:

Imaging in the infrared spectrum, often known as thermal imaging, is a diagnostic method that is both effective and systematic. During operation, an infrared camera is employed to do a scan of the PV array. The camera measures the temperature differences in the cells and modules that are caused by defect faults such as (a) interconnection failures or module wiring, (b) hot spots due to internal short circuits, defected bypass diodes, change in the value of series resistance, cell mismatch, and snail trails, and (c) cell cracks. These faults can all lead to an increase in temperature. The thermal approach is preferable for use in the examination of big PV installations. The use of thermal imaging for the purpose of defect detection and classification at the cell level is discussed in [17] and [18]. In all of these experiments, infrared (IR) pictures were captured using an infrared (IR) camera with the purpose of doing image processing in the future to determine the kind and position of defects. In [17], the temperature variance and mean value of each cell are computed, and cells are then categorised according on their temperature mean value in an effort to identify defective cells. The other research, on the other hand, relied on temperature gradient analyses to identify defective cells [18]. It has been suggested that thermal imaging may be used to discern the margins of photovoltaic (PV) modules by identifying distinct temperature variations between the metal frame and the solar cells that are located adjacent [18]. In point of fact, the location of the infrared camera, the distance from the PV array, and the need of ensuring that there is an overlap between successive photos are all problems that prevent accurate fault categorization and detection when employing this method.

Ultrasonicinspection:

Prior to the manufacture of PV modules, this technology is most often used for the purpose of locating cracks, voids, and de-bonded lamination structures. In addition to that, it finds unbounded cells inside a module and fractures caused by deterioration after the PV modules have been deployed. In each of these approaches, a moving ultrasonic transducer is paired with an x-y indication to perform the scanning of PV modules [19]. The attenuation of the ultrasonic signal as it passes through a tested material is measured using the transmission technique, and the x-y position information of defects is recorded. Using this procedure, the faults and their sizes may be identified. In contrast, the ultrasonic pulses that are reflected back from defects are measured in the second method, which is known as the pulse-echo method and is the one that has gained the most popularity. This provides a value on the z-axis in addition to the information regarding the x-y location and the size of the defect. This approach determines the factors that contribute to the deterioration of modules and provides the producers with the technical data necessary to improve the dependability of their products.

ElectroluminescenceImaging

Electroluminescence imaging, also known as EL imaging, is a technique that is used to test PV modules for defects such as fine cracks and broken gates, as well as to identify solar cells with different conversion efficiencies. These inefficiencies can be caused by an increase in cell series resistance and/or a reduction in cell parallel resistance. This technique involves injecting a ramping voltage into the module, which results in product electroluminescence that identifies non-uniformities and flaws in the circuit. The glow becomes apparent at a specific level of voltage, and it reveals faults and fractures that lower the efficiency of the cell. This kind of detection comes at a significant cost and can be carried out in an offline setting only [20]. During the stage of failure detection, cells that have red frames represent damaged cells or cells that have fractures, while cells that have yellow frames represent inactive cells.

Lock in Thermography(LIT)

The testing method known as "lock in thermography" is used to evaluate the amount of power that is lost in solar cells. This approach is distinct from the one that uses infrared light. It works by coupling an excitation device that can lock in with a power source in order to inject pulse current of varying modulation into a photovoltaic module. The system works on this principle. The cells that have defective shunts see an increase in temperature as a direct effect of the injected current. In addition, a thermography camera is used with the procedure in order to identify cells that have defective shunts. Altering the modulation of the injected current allows for the detection of a wide variety of shunt problems. This test may discover even very minor flaws [21-32], and it is often carried out offline, either in bright light or complete darkness, depending on the circumstances.

B. Electrical DetectionMethods

Climatic Data Independent(CDI)

This methodology makes use of several methods of detection that do not rely on climatic factors such as sun irradiance, temperature, humidity, or wind speed in any way. In this part, we will go over the two methods that are the most common when it comes to fault location in PV modules. The time domain reflector (TDR) is the first method, and the measurement of the earth's capacitor is the second (ECM). In both approaches, various measuring tools, such as an LCR meter (which measures the parameters of a PV circuit, including the inductor, the capacitor, and the resistor) and a function generator, are used. Experimental work conducted with time domain reflectometry was given in reference [22]. [22] In the TDR approach, the waveform shifts, and then the delay between the injected signal and the reflected signal is utilised to identify existing deterioration. This degradation might take

 Copyright © 2022. JCT Publications. All Rights Reserved

the form of an increase in the series resistance between modules and places in a PV string. TDR readings should be taken at regular intervals in order to examine for and identify array deterioration. Another experimental investigation [23] employed earth capacitance measurement, also known as ECM, to determine the disconnection point in the PV string without taking into account the influence of irradiance variation.

C. Comparison between measured and modeled PV system outputs (CMM) technique

Simulation models are used in the majority of techniques that make use of this method in order to predict the power outputs of the PV systems. The cell model parameters that are stated in equation (1) are computed using data taken from the actual world, and the output of the PV array is predicted on the basis of these calculations. The circumstances of the irradiance of the surroundings and the temperature of the module are also taken into consideration in order to ensure that the simulated model behaves similarly to how it does in real life [28]. A comparison is made between the projected outputs of a modelled PV system and the measured outputs of the corresponding DC side of the PV system in order to discover a variety of system defects as early as possible [31]. Instead of utilising a standard mathematical model, the authors of [32] created the PV model employing a PSIM-based element and offered an extend correlation function for defects detection. In a recent research (33), the primary PV module was developed by taking into account both the I-V characteristics and the behaviour of the module under actual work circumstances.

D. Machine learning (ML)techniques

Irradiance, temperature, humidity, wind speed, dust, rain, snow, shade, breakdown of individual cells, and age are some of the variables that may affect the performance and efficiency of PV panels. As a consequence of this, defining particular limits for defect detection might be challenging. Because machine learning techniques have the capacity to automatically learn and adjust certain settings based on a specific set of data [34], these approaches may be utilised to create a self-learning system and circumvent the constraint. Identifying and categorising errors has been accomplished via a number of different applications of machine learning. The algorithms that make up machine learning may be broken down into three distinct categories: supervised learning, unsupervised learning, and reinforcement learning. The supervised learning models, such as linear and logistic regression, multi-class classification, and support vector machine [35], are the ones that are used the most often in the field of machine learning. The trained model does not perform correctly in various seasons of the year [36], the quantity of data necessary for training is a considerable number, and the model is developed on a case-by-case basis. These are the three key limitations that are associated with the supervised learning models.

V.CONCLUSION

Here i Due to the nonlinear output characteristics of the system, there are still many obstacles to overcome when attempting to identify defects in PV systems. It is crucial to avoid damaging effects, but it might be a difficulty to provide early notice to the operators of the PV plant about the malfunctioning components so that they can take remedial action before the system fails completely. The regular functioning of a PV system may be disrupted if there are faults present, which will result in a decrease in power production and may even cause damage to the array. Increasing the grid's stability when integrated with intermittent renewable energy resources like solar photovoltaic (PV) systems is one of the most significant difficulties that has to be overcome. This task should be one of your top priorities.

Fault analysis is one of the most difficult aspects of constructing an integrated PV system into an existing electric grid. Therefore, it is very vital to conduct an analysis of the characteristics of the current, voltage, and output power in order to describe the impact of the faults that occur. In the present day, we do not have a trustworthy approach for the detection and diagnosis of errors that are only beginning to develop in the PV system. There is currently no method of defect detection in the solar photovoltaic sector that utilises a current-based approach. The nonlinear I-V characteristics of the PV system, the current-limiting nature of PV arrays, fault discrimination, high fault impedances, transient behaviour of the PV system, inverters faults, mismatch faults, and the limitations of existing monitoring and fault detection and diagnosis approaches in solar PV systems are some of the potential challenges.

The use of grid-connected photovoltaic systems (GCPVS) is increasing on all scales, including residential, commercial, and utility, as the total costs of installing and owning these systems continue to fall. Despite the fact that GCPVS come with a plethora of benefits, including a long working lifespan (25–30 years), cheap costs for operations and maintenance, and apparent environmental advantages over power plants that rely on fossil fuels, GCPVS also come with their own unique set of obstacles.

VI. CONCLUSION

In this work, numerous flaws that may develop in solar arrays and the techniques that can be used to identify them are discussed. According to the temporal features of the faults, there were regarded to be three distinct categories: permanent, incipient, and intermittent. Using these methods, flaws in a variety of PV system locations may be found. There are ways that can identify DC problems, whereas others can identify AC faults. This article examines common issues with the DC side of photovoltaic (PV) systems (PV panels), their causes, the effects those causes have on PV performance, as well as diagnosis and forecast. In the course of this research, defects will be categorized as either permanent, intermittent, or transient, in addition to incipient. If issues are caught in their early stages, they may often be corrected before they become permanent. In this review research, the

 Copyright © 2022. JCT Publications. All Rights Reserved

most important technologies for detecting PV panel breakdown are categorized according to the detection and prediction methodologies they use. The research identifies the most effective ways for determining whether a PV array has failed.

REFERENCE

[1] K. Arani, S. M., Hejazi, M.A., 2016, "The Comprehensive Study of Electrical Faults", in PV Arrays. J. Electr. Comput. Eng.2016.

[2] Madeti, S.R., Singh, S.N., 2017a, "Monitoring system for photovoltaic plants: A review", in Renew. Sustain. Energy Rev. 67, pp.1180–1207.

[3] Triki-Lahiania, A., Abdelghania A.B., Slama-Belkhodjaa, I., 2018, "Fault detection and monitoring systems for photovoltaic installations: A review", in Renew. Sustain. Energy Rev. 67,2680–2692.

[4] Firth,S.K.,Lomas,K.J.,Rees,S.J.,2010,"Asimplemode lofPVsystem performance and its use in fault detection", Sol. Energy 84 (4), pp. 624– 635.

[5] M. K. Alam, F. H. Khan, J. Johnson, and J. Flicker, 2013, "PV faults: Overview, modeling, prevention and detection techniques", in IEEE14th Workshop on Control and Modeling for Power Electronics (COMPEL), pp.1–7.

[6] Singh, G. K., 2013, "Solar power generation by PV (photovoltaic) technology: A review", in Energy 53,1-13.

[7] Masmoudi F., Salem, F. B., Derbel, N., 2016, "Single and double diode models for conventional mono-crystalline solar cell with extraction of internal parameters", in IEEE 13th International Multi-Conference on Systems, Signals & Devices (SSD), pp.720-728.

[8] Bastidas-Rodriguez J. D., Petrone G., Ramos-Paja C. A., Spagnuolo G., 2013, "Photovoltaic modules diagnostic: An overview", in IECON2013-39thAnnualConferenceoftheIEEEIndustrialElectronicsSociety,pp. 96-101.

[9] Walker, G., 2001, "Evaluating MPPT converter topologies using a matlab PV model", in Journal of Electrical and Electronics Eng., 21(1),49.

[10] Maghami, M. R., Hizam, H., Gomesa, G., Radzia, M. A., Rezadad, M. I., Hajighorbani, S., 2016, "Power loss due to soiling on solar panel: A review", in Renew. Sustain. Energy Rev. 59, pp.1307-1316.

[11] Stettler, S., Toggweiler, P., Wiemken, E., Heydenreich, W., Keizer, A., Sark, W., Feige, S., Schneider, M., Heilscher, G., Lorenz, E., et al, 2005, "Failure detection routine for grid-connected PV systems as part of the pvsat-2 project", in Proceedings of the 20th European Photovoltaic Solar Energy Conference & Exhibition, pp.2490–2493.

[12] Alsayid, B. A., Alsadi, S. Y., Jallad, J. S., Dradi, M. H., 2013, "Partial shading of PV system simulation with experimental results", Smart Grid & Renew. Energy, 4(6), pp.429–435.

[13] Zhao,Y.,Palma,J.,Mosesian,J.,Lyons,R.,Lehman,B.," Line–LineFault Analysis and Protection Challenges in Solar Photovoltaic Arrays", in IEEE Trans. on Industrial Electronics, Vol. 60(9), pp. 3784-3795.

[14] Gokmen, N., Karatepe, E., Celik, B., Silvestre, S., 2012, "Simple diagnostic approach for determining of faulted PV modules in string based PV arrays", Solar Energy, 86(11), pp.3364-3377.

[15] Zhao, Y., Lyons, Jr. R., 2011, "Ground Fault Analysis and Protection in PV Arrays", PVPN1: Ground-Fault Analysis and Protection in PV Arrays, Tech Topics: Photovoltaic Protection Note 1, Issue1.

[16] Packard C. E., Wohlgemuth1, J. H., Kurtz, S. R., 2012, "Development of a Visual Inspection Checklist for Evaluation of Fielded PV Module Condition", in PV Module Reliability Workshop, NREL,2012.

[17] Vergura,S.,Marino,F.,Carpentieri,M.,2015,"Processin ginfraredimage of PV modules for defects classification," in IEEE Proceedings of the International Conference on Renewable Energy Research and Applications (ICRERA '15), pp.1337–1341.

[18] Guerriero, P., Cuozzo, G., Daliento, S., 2016, "Health diagnostics of PV panels by means of single cell analysis of thermographic images", in Proceedings of the IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC'16).

[19] Hund, T.D., King, D.L., 1995, "Analysis techniques used on field degraded photovoltaic modules", in NASA STI/Recon Technical Report N, p.96.

[20] Koch, S., Weber, T., Sobottka, C., Fladung, A., Clemens, P., Berghold ,J., 2016," Outdoor electro luminescence imaging of crystalline photovoltaic modules: comparative study between manual ground-level inspections and drone-based aerial surveys", in 32nd European Photovoltaic Solar Energy Conference and Exhibition, pp.1736-1740.

[21] Breitenstein, O., Bauer, J., Trupke, T., Bardos, R.A., 2008, "On the detection of shunts in silicon solar cells by photo-and electroluminescence imaging", in Prog. Photovoltaics Res. Appl., 16 (4), pp.325–330.

[22] Takashima, T., Yamaguchi, J., Otani, K., Kato, K., Ishida, M., 2006, 2"Experimental studies of failure detection methods in PV module strings", in Photovoltaic Energy Conversion, Conference Record of the IEEE 4th World Conference, vol. 2, pp.2227–2230.

[23] Takashima,T.,Yamaguchi,J.,Otani,K.,Oozeki,T.,Kato ,K.,Ishida,M.,2009,"Experimental studies of fault location", in PV module strings. Sol. Energy Mater. Sol. Cells 93 (6), pp.1079–1082.

[24] Vergura S, Accaciani G, Amoruso V, Patrono G, Vacca F., 2009, "Descriptive and inferential statistics for supervising and monitoring the operation of PV plants", in IEEE Trans Ind Electron, 56, pp.4456–63.

[25] Lin, P., Lin, Y., Chen, Z., Wu, L., Chen, L., Cheng, S., 2017, "A density peak-based clustering approach for fault diagnosis of photo voltaic arrays" Int. J. Photo Energy.

[26] Miwa, M., Yamanaka, S., Kawamura, H., Ohno, H.,

 Copyright © 2022. JCT Publications. All Rights Reserved

2006, "Diagnosis of a power output lowering of PV array with a (−dI/dV)-V characteristic", in Photovoltaic Energy Conversion, Conference Record of the IEEE 4th World Conference, vol. 2, pp.442–2445.

[27] Kaplanis, S., Kaplani, E., 2011, "Energy performance and degradation over 20 years performance of BP c-Si PV modules", in Simulation Modelling Practice and Theory, 19(4), pp.1201-1211

[28] Chouder, A., Silvestre, S., 2010, "Automatic supervision and fault detection of PV systems based on power losses analysis", in Energy Convers. Manage. 51 (10), pp.1929–1937.

[29] Silvestre S, Chouder A, Karatepe E., 2013, "Automatic fault detection in grid connected PV systems", in Sol Energy, 94, pp.119–27.

[30] Madeti,S.R.,Singh,S.N.,2017,"Onlinefaultdetectiona ndtheeconomic analysisofgrid-connectedphotovoltaicsystems",inEnergyVol.134,pp. 121-135.

[31] Drews,A.,DeKeizer,A.C.,Beyer,H.G.,Lorenz,E.,Betc ke,J.,VanSark, W.G., Heydenreich, W., Wiemken, E., Stettler, S., Toggweiler, P., Bofinger, S., 2007, "Monitoring and remote failure detection of grid-connectedPVsystemsbasedonsatelliteobservations",in Sol.Energy81 (4), pp.548–564.

[32] Chao, K.H., Ho, S.H., Wang, M.H., 2008, "Modeling and fault diagnosis of a photovoltaic system", Electr. Power Syst. Res. 78 (1), pp.97–105.

[33] Chouder, A., Silvestre, S., 2009, "Analysis Model of Mismatch Power Losses in PV Systems", in J. Sol. Energy Eng 131(2),024504.

[34] Daliento, S., Chouder, A., Guerriero, P., Pavan, A.M., Mellit, A., Moeini, R., Tricoli, P., 2017, "Monitoring, Diagnosis, and Power Forecasting for Photovoltaic Fields: A Review", in International Journal ofPhotoenergy,Vol. 2017, 1356851

[35] Baharin KA, Abd Rahman H, Has-san MY, Gan CK., 2014, "Hourly irradiance forecasting in malaysia using support vector machine, in Energy Conversion (CENCON), IEEE Conference on, pp.185–90.

[36] Youssef, A., El-Telbany, M., Zekryb, A., 2017, "The role of artificial intelligence in photo-voltaic systems design and control: A review", in Renew. Sustain. Energy Rev. 78, pp.72-79.

[37] Hern´andez,J.C.,PedroG.Vidal,2009,"Guidelinesforp rotectionagainst electric shock in PV generators", in IEEE Tran. Energy Conversion, 24(1).

[38] Flicker, J.D., Johnson, J., 2013, "Photovoltaic ground fault and blind spot electrical simulations", in Sandia Report,SAND2013-3459.

[39] Ball, G., Brooks, B., Johnson, J., Flicker, J., Rosenthal, A., Wiles, J., Sherwood, L., Albers, M., Zgonena, T., 2013, "Inverter ground-fault detection 'blind spot' and mitigation methods", Solar Amer., Board Codes Stand. Rep.(June).

[40] Hernández, J.C., Vidal, P.G., Medina, A., 2010. Characterization of the insulation and leakage currents of PV generators: Relevance for human safety, in Renewable Energy 35 (3), pp.593–601.

[41] Johnson, J., Kang, J., 2012, "Arc-fault detector algorithm evaluation method utilizing prerecorded arcing signatures", in 38th IEEE Photovoltaic Specialists Conference (PVSC), pp.1378–1382.

[42] Johnson, J., Kuszmaul, S., Bower, W., Schoenwald, D., 2011, "Using PV module and line frequency response data to create robust arc fault detectors", in Proceedings of the 26th European Photovoltaic Solar Energy Conference and Exhibition, pp.05–09.

[43] Johnson, J., Pahl, B., Luebke, C., Pier, T., Miller, T., Strauch, J., Kuszmaul, S., Bower, W., 2011, "Photovoltaic DC arc fault detector testing at Sandia National Laboratories", in Photovoltaic Specialists Conference (PVSC), 2011 37th IEEE, pp.003614–003619.

[44] Schimpf,F.,Norum,L.E.,2009,"Recognitionofelectric arcingintheDC- wiring of photovoltaic systems", in Telecommunications Energy (INTELEC) International IEEE Conference, pp.1–6.

[45] Alam, M.K., Khan, F.H., Johnson, J., Flicker, J., 2014, "PV arc-fault detection using spread spectrum time domain reflectometry(SSTDR)",in Energy Conversion Congress and Exposition (ECCE), IEEE conference, pp.3294–3300.

[46] Strobl C., Meckler P., 2010, "Arc Faults in Photovoltaic Systems", in Proceedings of the 56th IEEE Holm Conference on Electrical Contacts (HOLM),11639108.

 Copyright © 2022. JCT Publications. All Rights Reserved