# A Review on Grid Connected PV System Fault Diagnosis Methods

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***Abstract*—In the recent years the detection as well as the identification of various faults in the Photovoltaic (PV) system applications has been attracting several researchers across world. Photovoltaic (PV) power generation systems are very good in working with several climatic outdoor conditions, Hence the present faults can see to occur within the PV arrays in PV systems. Online fault detection for the PV arrays is important to improve the system's reliability, safety and efficiency. There are some researches shows the working of the potential faults in order to monitor the faults as well as to make identifications through fault diagnosis that have been elaborated in order to develop and to modify the present problems solving method so to detect early faults in Photovoltaic (PV) system present in the system operators. In this paper author tries to put information precisely taken forward from previous research. The author also explains about the latest trends applied in the PV system fault diagnosis as well as protection system. In this paper a new approach towards literature has been introduced associated with the fault studies present in the PV systems. In this survey paper author has explained about further discussions over how specific solutions can be provided to make a comprehensive solution to the fault problems of the PV system.This paper presents the classification and detection of faults in a distributed generation, particularly Photovoltaic (PV) Grid-Connected system. The initial step in fault detection of PV system is recognition, investigation and classification of all possible faults that maybe occur in the system.***

***Keywords--Detection and Identification, Fault Diagnosis, Monitoring Systems, Protection Systems, PV Systems.***

## I. INTRODUCTION

The utilization of solar energy for electricity and heat energy sources has increased significantly over the last decade. More specifically, photovoltaic (PV) systems have established an important role in the electricity energy sectors by contributing more than 10% electricity energy supply nowadays. There are many reasons that grid connected PV systems are proliferating, such as reasonable cost of installation along with fast energy and investment payback that includes possible incentives to customers. In view of this, a fault-detection method based on voltage and current observation and evaluation is presented in this paper to detect common PV array faults, such as open-circuit, short-circuit, degradation and shading faults. In order to develop this detection method, fault characteristic quantities (e.g., the open-circuit voltage, short-circuit current, voltage and current at the maximum power point (MPP) of the PV array) are identified first to define the voltage and current indicators; then, the fault-detection thresholds are defined by utilizing voltage and current indicators according to the characteristic information of various faults; finally, voltage and current indicators evaluated at real-time voltage and current data are compared with the corresponding thresholds to detect potential faults and fault types. Power generation based on PV sources has gradually increases during the last few decades [1]. This development has been matched with research into more efficient solar panels. Efficiency is calculated as the ratio of incident sun energy to the maximum attainable output power, with the recent record being an efficiency of 44.7% [2]. Along with research into solar panels, there is also an interest in the adjacent equipment. The efficiency of solar panels naturally range throughout the system, since any losses will disturb the final efficiency of the whole system. The standard configuration of a Grid Connected PV System (GCPV) is shown in Figure 1.

Recently, the area PV inverters has progressed to distributed systems of inverters,where a small inverter module is connected to every panel [3]. This is favorable since each panel can be enhanced locally, thereby improving the energy harvest. Besides increased efficiency, this also allows individual measurements of solar panels. These new capabilities make new possibilities in monitoring of the health of solar panels that is technically termed as fault detection. The output power degradation not only depends on the PV panels. The occurrences of faults in any other components such as Maximum Power Point Tracking (MPPT), inverter, Voltage Source Converter (VSC) and grid in the power system may results in output power change [5-10].

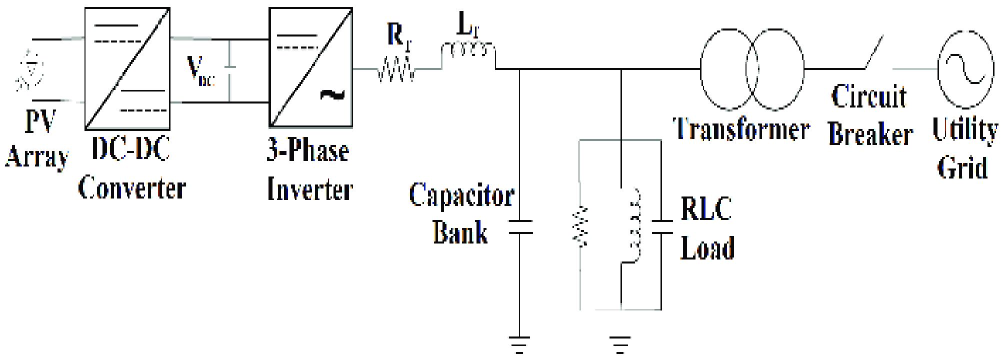


Figure 1: Grid Connected PV System.

## II. LITERATURE SURVEY

In this section an overview of various intelligent techniques by using the most popular methods in order to solve various types of engineering problems. Now days it includes the problems of identification as well as fault diagnosis in the PV systems.The adverse advantage can be taken from these type of methods contains symbolic reasoning, flexibility as well as the ability so to explain results. These methods are also capable of making quick decisions as well as analyze thenon-linear, large, complex as well as even incomplete data patterns.

On comparing with some standard linear models for optimization methods, the intelligent computational methods provide an accurate solution for multivariable problems without any further knowledge of internal system parameters. So, for these methods only a training process is required to directly determine the output parameters. These solutions are obtained without solving any non-linear mathematical equations or making statistical assumptions as in the conventional optimization methods. A summary of intelligent methods application is provided in Table 1.

### 1. Artificial Neural Network

In this paper author [9] introduced a deep learning that is artificial neural network (ANN) is the most fundamental model used to detect and classify faults occurring inPV systems. This method is very helpful in order to detect the partial shading faults present in the PV systems for the detection done on the basis of various inputs. In this paper author makes a comparison in between the current outputs, current, voltage as well as maximum power point between the ideal model and output estimation from neural network. The use of ANNs is also recognized for monitoring and diagnosing of real-time PV plant management. An ANN knowledge-based diagnosis system has capabilities to estimate the key components that can aid in damage prevention, extend critical components life-time.

**Conclusion:**This algorithm improve overall system performance and reliability, minimize off-line analysis effort and maintenance costs, and allow remote plant monitoring, diagnosis and evaluation.

### 2. Decision Tree Algorithm

In this paper [10] author proposed intelligent technique based machine learning methods have been approached for fault detection and diagnosis that could be the prominent solution for fault detection in PV systems. This work author applied a decision tree algorithm which is then applied to the grid connected PV systems. A learning method based non-parametric model is used to predict the performance of PV systems, while a data set under different climate conditions is collected through acquisition system. The target of this study is to estimate whether the state of PV system is in either normal or faulty conditions. The faulty conditions are classified as string, short circuit or lineline faults. The testing results indicate the high prediction performance and accurate diagnosis that imply the robustness, effectiveness and efficiency of proposed method. Identifying a fault condition in PV systems is quite tricky because the non-linear characteristic of the system outputs is highly susceptible to climate conditions. For PV system diagnostics, common potential problems exist regarding the performance, modelling and sampling of experimental data.

**Conclusion:**The performance is sometimes not satisfied due to the lack of monitored fault information. The appropriate model is not reached due to less efficient data collection for model training. Also, it is quite difficult to obtain the fault data samples from field experiments.

Therefore, the new approach of fault detection based machine learning methods is introduced using a vector of seven dimensions based on the I-V parameters response to environmental conditions. This vector is proposed as the input to the fault diagnosis model, using the emerging kernel based extreme learning machine (KELM) and this will be described in the next paper.

**3. Kernel Based Extreme Learning Machine**

In this paper [11] author introduced KELM which is characterized as having extremely fast learning speed and good generalization performance. The NelderMead Simplex (NMS) optimization method is utilized to optimize the KELM parameters which influence the classification performance. Through simulation and experimental results, the optimized KELM approach for fault diagnosis of PV systems is highly accurate, reliable with improved generalization performance. With high efficiency being the main target of PV system development nowadays, there is a trend to increase in PV plant capacity. The provision method for PV fault identification is an important tool in the effort to increase the PV system efficiency.

**Conclusion:**These methods have achieved successful identification and localization of fault types under different testing scenarios.

**4. Improved Real Coded Genetic Algorithm**

In this paper [12] author proposed the Improved Real Coded Genetic Algorithm (IRCGA) is another meta-heuristic optimization approach that can be used to detect, localize and distinguish the open and short-circuit faults under non-uniform sunlight intensity and temperature distribution. After extensive simulation performance, the IRCGA method accurately estimated the possible fault location and type of faults. In this case, the meta-heuristic optimization techniques, such as Genetic Algorithm (GA), Tabu Search (TS) algorithm and Grey Wolf Optimization (GWO) are utilized as the fault diagnostic tools to detect and classify the open circuit and short-circuit faults under nonuniform distribution of sunlight intensity and temperature.

**Conclusion:**Providing efficient and effective fault diagnosis methods is necessary to ensure the continuous power production in PV systems.

**5. Wavelet Packet Transform**

In this paper [13] author takes forward previous work by using wavelet modification method called wavelet packet transform (WPT) that can be used to detect the different types of faults in grid connected PV systems. The research results show that the performance of the WPT method is better than the conventional wavelet transform in detecting faults from normal operation conditions under different testing scenarios measured by the energy output and standard deviation performance index. In comparison, the wavelet transform method uses an approach to avoid several problems in conventional fault detection systems [14]. This method reducesthe need for additional hardware and sensors that impacts the cost. The method is also less dependent on changes in inverter specifications. The diagnostic function design of this multilevel decomposition wavelet method is based upon the normalized standard deviation of the wavelet coefficients.

**Conclusion:**It is shown to be highly efficient and accurate in detecting the fault location including in the inverter.

**6. Conventional FDD Algorithm**

In this paper [17] author introduced FDD approach In spite of the fact that PV varieties of such frameworks are strong, they are not safe to deficiencies. To ensure dependable force gracefully, monetary returns, and wellbeing of the two people and hardware, exceptionally precise issue recognition, conclusion, and interference gadgets are required. In this paper, a diagram of four significant PV exhibit faults and their causes are introduced. In particular, ground fault, line-line shortcoming, curve deficiency, and problem area issue have been secured. Next, customary and propelled issue recognition and conclusion (FDD) strategies for dealing with these faults are looked into.

**Conclusion:**a solitary assessment metric has been proposed and used to assess the exhibitions of the progressed FDD methods.

**7. Multilayer Perceptron (MLP) ANN**

In this paper [18] author’s primary goal of this work is to introduce a complex strategy dependent on fake neural systems ANN for diagnosing; distinguishing and absolutely characterizing the fault in the sunlight based boards so as to stay away from a fall in the creation and execution of the photovoltaic framework. The work set up in this paper means in the lead position to propose a strategy to distinguish conceivable different blames in PV module utilizing the Multilayer Perceptron (MLP) ANN arrange. The created fake neural system requires a huge database and intermittent preparing to assess the yield boundaries with great exactness. To assess the exactness and the presentation of the proposed approach, a correlation is completed with the great technique (the strategy for thresholding).

**Conclusion:**To test the adequacy of the proposed approach in recognizing and ordering various deficiencies, a broad recreation is done utilizing Matlab SIMULINK

**Table 1: Summary of Intelligent Computational Methods.**

| Authors | Methods | Purposes | Tasks |
|---|---|---|---|
| H.Mekki, | Artificial | Detection | Faults in |

| | | | |
|---|---|---|---|
| A.Mellit, H.Salhi [9] | Neural Network Decision Tree Algorithm | & diagnosis | general Partial shading patterns Faults in grid connected PV systems |
| RabahBenkercha, Samir Moulahoum [10] | Optimized Kernel based Extreme Learning Machine (KELM) | Diagnosis | Improvement model in fault studies |
| Zhicong Chen, Lijun Wu, Shuying Cheng [11] | Meta-Heuristic Optimization | Diagnosis & Identification | Location and types of open-circuit and shortcircuit (SC) faults |
| Saborni Das, AbhikHazra, MousumiBasu [12] | Improved Real Coded Genetic Algorithm | Diagnosis Strategy | Normal and fault conditions |
| Prakash K. Ray, AsitMohanty, Basanta K. Panigrahi [13], il-SongKim [14] | Wavelet Transform | Detection & identification Detection algorithm | Fault locations and inverter components |
| Albert Yaw Appiah [17] | FDD | Diagnosis Strategy | Recognize faults in a variant ways |
| AichaDjalab [18] | Multilayer Perceptron (MLP) ANN | Multilayer Perceptron (MLP) ANN | It test the adequacy of the proposed approach in recognizing and ordering various deficiencies |

In the above table 1 the comparative analysis over previously used algorithms is given.

## III. CLASSIFICATION OF FAULTS IN GCPV SYSTEM

Faults in PV system can be identified in two side of the system: DC side and AC side, the interface between this to part is DC/AC inverter that connected to grid [11-15].The classification of faults is shown in Figure 2.

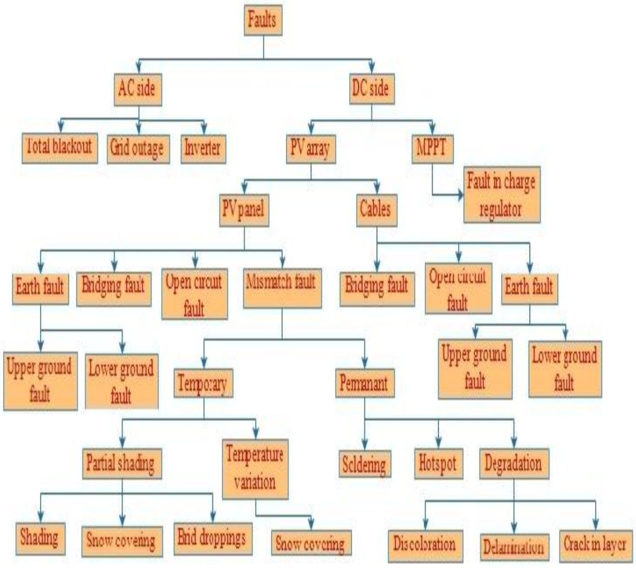


Figure 2: Classification of faults.

### *A. Faults in DC side*

The faults occurs in DC side of the GCPV system are classified into two major types: Fault in PV array and Fault in MPPT.

### *A.1. Faults in PV Array*

Faults in PV arrays involve two main groups, PV panel fault and cabling. The most common types of fault in PV Panel/Module are Earth Fault, Bridge Fault, Open Circuit Fault and Mismatch Fault. a) PV panel/Module Faults

### *1) Earth Fault*

Earth fault occurs when the circuit develops an unintentional path to ground.Two types of grounding shall be provided for PV system such as system grounding and equipment grounding. In system grounding, the negative conductor is grounded through the Earth fault protection device (GFPD) in the PV inverter. The exposed non-current-carrying metal parts of PV module frames, electrical equipment, and conductor enclosures should be grounded in equipment grounding.Two types of Earth faults namely Lower Earth fault and Upper Earth fault can occur.In Lower Earth fault, the potential fault point is upper than half of the maximum voltage power point. And the Upper Earth fault will create large backed current and very high Earth-fault current. Without any sensor, these faults areidentified, when the sign of the monitored primary current of the solar inverter is changed. When the primary current becomes negative, the solar inverters initiate a controlled internal short circuit.

***2) Bridging Fault***

When low- resistance connection recognized between two points of different potential in string of module or cabling, the bridging fault will occur. Insulation failure of cables such as an animal chewing through cable insulation, mechanical damage, water ingress or corrosion cause these faults.

***3) Open Circuit Fault***

An open circuit fault occurs, when one of the current-carrying paths in series with the load is broken or opened. The poor connections between cells, plugging and unplugging connectors at junction boxes, or breaks in wires cause these fault.

***4) Mismatch Fault***

When the electrical parameters of one or group of cell are changed from other, the mismatches in PV modules will occur. These fault results in irreversible damage on PV modules and large power loss. These faults can be classified into permanent and temporary mismatches. Temporary mismatches occurs when a part of the panels array are shaded by shade from the building itself, light posts, chimneys, trees, clouds, dirt, snow and other light-blocking obstacles. Non- uniform temperature can identified due to snow covering. Permanent mismatch occurs due to faults in hotspot, soldering and degradation. Hot spot heating happens when the operating current exceeds the reduced short circuit current of a shadowed or faulty cell or group of cells within the module. Soldering fault can be identified in resistive solder bond between cell and contacted ribbons. Discoloration, delamination and transparent layer crack result in degradation fault.

***B) Fault in Cables***

Bridging Fault, Open-Circuit fault and Earth Fault are occur in power line carrier and cabling system. An aged connection box at the back side of a solar panel or in the corner and bend aria of cable cause bridging fault. Upper earth and lower earth faults occur between panels and ground. It results in dropped output voltage and power, and can be dangerous if the leakage currents are running through a person.

***A.2. MPPT Fault***

MPPT increases the power fed to the inverter from PV array. The performance of MPPT degrades when the failure occurs in the charge regulators. The output voltage and the output power reduces when fault occur in MPPT.

***B. Faults in AC Side***

In AC side two types of faults can be identified: total black out which measured as exterior fault for system, lighting and unbalanced voltage or grid outage for AC part defect such as weaker switch, over current or over voltage and etc. Meanwhile most PV inverters having transformers that could give good galvanic isolation between PV arrays and utility grids and perfect electrical protections. The AC output power will become low and DC output power remains the same, when there is a fault in the inverter. This details confirms that there is no possibility that a wire between modules/strings and inverter was broken or a breakdown occurs in strings and/or modules. So, fault in the inverter is the reason for power loss.

## IV. PROBLEM DEFINITION

1. New faults are emerging day by day they may create a major problem as they are still undetected. Overall there is a continuous need to develop new techniques & improvement is required in existing techniques especially in equivalent model of PV cell.
2. Recently two diode equivalent model is proposed instead of single diode equivalent model, on which more work is yet to be one. Most of the Experimental work done is a system specific. A generalized algorithm may be develop for fault detection & diagnosis.
3. The current systems developed are only for detection of two or three faults at a time. An integrated system can be develop which can detect multiple faults.
4. Many algorithms are justified theoretically so they can be verified experimentally.
5. Simple & cost effective system can be developso these systems can be utilized for the monitoring & supervising of small PV System & Power plants.
6. Processing time for fault detection or execution time required to detect a particular fault is still an area for research.

## V. CONCLUSION

In this paper the overview of different faults occurred in photovoltaic system are reviewed. The various strategies, models accessible in the literature section to assess the outputs which are generated intensity of PV cell are altogether looked into. Distinctive summed up and custo,ized programming projects are accessible for recreation of their models alongside MATLAB/SIMULINK. Alongside this, outline of various procedures/algorithms/strategies accessible for fault discovery and analysis for photovoltaic framework are concentrated in subtleties and in near way. So as to build the adequacy, unwavering quality of a PV framework a solid fault finding strategy is must. The strategy ought to react to the fault in a brisk way with great precision and numerous calculations in writing tends to this concern. Online issue location is a zone which is as yet ignored. The speculation cost to build up an administrative and observing framework is still high, so it is extremely hard to suit little power plants into it. Single framework tends to a couple of shortcomings as it were. Basic faults, for example, faults because of Major delamination are not address yet.

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