An Efficient Fault Diagnosis Scheme for PV System using Information at the DC Side

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***Abstract:** In this paper the detection of fault is done as, PV system converts the solar energy into electrical energy and this energy is either stored in a battery bank in a standalone system or transmitted to the grid through grid interfacing power electronic converters. PV fault protection/detection and isolation devices of multiple kinds are installed in a PV station to isolate the PV converters/grid from the PV array during any fault in the PV system. Although, the rest of the power processing or storage units are isolated from the faulty PV array, the solar cells remain active and may produce significant current flow within the modules that may result in damages even catastrophic fire. The conducted work within the scope of this paper describes various faults in a PV plant, and explains the limitations of existing detection and suppression techniques. Different fault detection techniques proposed in literatures have been discussed and it was concluded that there is no universal fault detection technique that can detect and classify all faults in a PV system. Moreover, this digest proposes a transmission line model for PV panels that can be useful for interpreting faults in PV using different refelectometry methods.*

***Keywords:** Photovoltaic system, Fault Detection, Artificial Intelligence, Probabilistic Neural Network.*

I. INTRODUCTION

Since, solar energy has been widely used because of its inexhaustible and environmentally friendly advantages [1]. Under complex and changeable climate conditions, operational faults in a photovoltaic (PV) system have always been one of the important factors affecting its power-generation efficiency [2, 3]. However, faults in the direct current (DC) side of a PV system, such as open-circuit, short-circuit, degradation and shading faults, are often difficult to avoid and can result in system energy loss, PV module lifespan reduction, or even serious safety concerns.

Existing fault-detection methods include those based on thermal infrared detection, time domain reflectometry, artificial intelligence algorithm, mathematical model analysis methods, and so on. The thermal infrared detection method detects and identifies faults by an infrared scanner to measure the surface temperature of the PV modules for abnormal heat caused by faults. Nian et al. [6] utilizes the principles of the semiconductor's electroluminescence to design image acquisition devices that can obtain infrared image of PV modules. The devices can detect the faults including black pieces, fragmentation, broken grid and crack for the PV modules. Peizhen and Shicheng [7] propose a method that can automatically analyze and recognize the working status of the PV arrays based on infrared image analysis. The method can accurately identify the normal, shading and degradation status of the PV modules. However, the thermal infrared detection method mainly focuses on the detection of hot spot faults inside a PV array. The time domain reflectometry method needs to inject a pulse signal into the series PV modules circuits of a PV array, and then identifies the fault status of the PV array by comparing the input pulse signal with the feedback output signal. Takashima et al. [8,9] applies the time domain reflectometry method to detect degradation faults and locate fault positions of the PV module in a PV array by the change of response waveform. However, when utilizing the time domain reflectometry method to detect faults, the PV system must be turned off, which will critically affect the system's productivity.

This is beneficial since each panel can be optimized locally, thereby increasing the energy harvest. In addition to increased efficiency this also allows individual measurements of solar panels. These new capabilities provide new possibilities in monitoring of the health of solar panels. This process, known as fault detection, is an active research area. Fault detection aims to detect faulty and degraded solar panels as soon as possible. Degradation occurs naturally in solar panels and it is of interest to quantify the degradation rate over time.

II. LITERATURE REVIEW

In this section an overview of the previously proposed papers is given this will ultimately help to examine the disadvantages, advantages as well as the proposed work.

The k-nearest neighbours rule has been used in the classification and regression for string connected fault identification and diagnosis of PV systems [15]. This strategy is completely ready to recognize and characterize various sorts of issues continuously, for example, open circuit, line to line issues, halfway shading with/without sidestep diode faults and incomplete shading with rearranged sidestep diode deficiencies. Also, the proposed technique precisely follows the exhibition of PV frameworks at various insolation and temperature levels. In contrast with this technique, shading issues and deficiency location on the DC side of a framework associated PV framework are explored with exponentially weighted moving normal (EWMA) control diagram. The EWMA strategy had the option to distinguish the boundary changes between the shortcoming and ordinary conditions [2].

The instrument is to perceive the ordinary yield boundaries of PV framework, for example, most extreme force, current and voltage under various irradiance and cell temperature. The lingering, the contrast between the deliberate and anticipated yield from the single diode model, is taken as the fault pointer of PV frameworks. At that point, an EWMA outline is used to screen the non-corresponded residuals to recognize the sort of deficiency. For checking execution of PV frameworks, the factual methodology based univariate and multivariate exponentially weighted moving normal (EWMA) graphs approach is again used to recognize and analyze the deficiencies on DC side of PV framework [16]. A deviation number of electrical boundaries of PV frameworks under issue and typical conditions is resolved as the fault marker. Truth be told, the proposed multivariate EWMA can't recognize the deficiency types, except if the univariate EWMA plot is sent later to distinguish the short out, open-circuit and shading issues.

The observing capacity of shortcomings in PV frameworks is improved through the upgraded techniques for factual disappointment distinguishing proof [17]. The objective of the proposed technique is to diminish the support alert and missed recognizable proof rates by sending the multiscale-weighted summed up probability proportion test (MS-WGLRT) strategy.

The explanation behind this methodology is the multiscale nature may give better power to clamor and checking quality contrasted with the freely summed up probability proportion test strategy. Programmed recognition and determination of potential issues in network associated PV frameworks dependent on factual strategies thinking about atmosphere information and electrical boundaries are introduced as another option [18].

The calculation of fault identification based factual t-test is to look at the deliberate and perfect yield power, while the area of issue is resolved from the deliberate and perfect estimations of DC capacity to voltage proportion. This technique is successfully used to recognize various blames in PV board, PV string and MPPT controller. In the mean time, comparative factual techniques for t-tests and f-tests are utilized to examine the impact of splits on PV board electroluminescence estimations [19].

III. PV SYSTEM WORKING

A PV system usually undergoes an optimization procedure guided by complex objective functions embedding various and sometimes contradictory criteria, in order for it to result as the best trade-off in the context of a specific application. During the exploitation time of PV systems, methods of automatic control and signal processing are necessary in order to optimize its dynamic performance, reactivity to the variability of the primary energy source, i.e., the light, and robustness to any kind of disturbances. One of such particular topology makes the object of this paper.

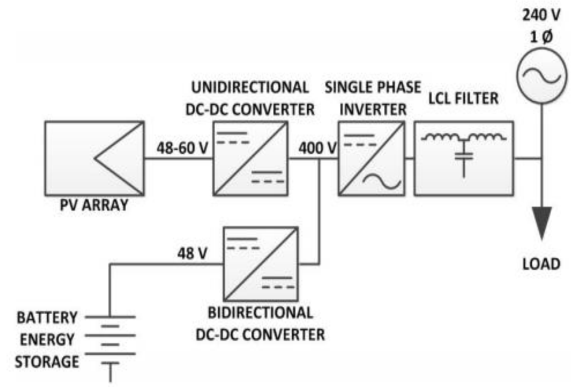

Figure 1: Typical PV power system block diagram.

The problem is to find a robust control strategy of extracting the maximum power available from a PV architecture in which the PV panels may undertake supplementary constraints when exposed to strongly variable irradiance conditions. This paper is organized as follows. In the next section the structure, operation and steady-state analysis of the considered DC converter PV topology are presented.

MPPT Algorithms

Many different MPPT algorithms have been developed and used [20], [21]. Some are very simple, and can be easily accomplished using analog control techniques. One of the simplest is the CV technique, which maintains the PV array voltage at a predetermined limit, which corresponds to the MPP under a specific set of atmospheric conditions [21]. When operating outside of the predetermined conditions, this will only approximate the true MPP. Other approximate MPPT techniques include the short current pulse and open circuit voltage techniques. The SCP periodically shorts the PV module (or array). A current reference can be calculated as a percentage of the short circuit current (typically 92%) [21].

The OCV works similarly by open circuiting the array and determining a voltage reference based on the open circuit voltage (generally around 76% of the open circuit voltage)

[21]. Each of these suffers the disadvantage of requiring additional switches to short or open the PV modules (or arrays). In addition, no power is produced during the period in which the panel is in a short or open condition [21].

Fault Detection and Diagnosis

With the research advances in ANNs and the advent of deep learning algorithms using deep and complex layers, novel classification models have been developed to cope with fault detection and diagnosis.[28] Most of the shallow learning models extract a few feature values from signals, causing a dimensionality reduction from the original signal. By using Convolutional neural networks, the continuous wavelet transform scalogram can be directly classified to normal and faulty classes. Such a technique avoids omitting any important fault message and results in a better performance of fault detection and diagnosis.[29] In addition, by transforming signals to image constructions, 2D Convolutional neural networks can be implemented to identify faulty signals from vibration image features.[30]

DC CONVERTER DESIGN

Discrete Controller or DC

A discrete controller was developed using the previously developed analog controller. For the discrete controller, the analog PWM was replaced with a discrete PWM [25].

The PI controllers were replaced with discrete versions. Several methods for developing discrete versions of PI controllers exist [25]. For the backward Euler method output of the integration, ( ), utilizes the following expression:

$$M_1 (k) = K_1 T_1 * E (k) - m_1 (k-1) \ldots\ldots\ldots 1$$

Where K_1 is the integral gain,

T_s is the sampling period,

and E(k) is the error for sample k [25].

The digital expression of the complete PI loop can then be expressed as:

Where K_p is the proportional gain.

$$M (k) = m(k-1) + K_p + (K_1 T_s) * E(k) - Kp * E (k-1) \ldots\ldots\ldots 2$$

An important design criterion for DC converters for PV applications is the ability to produce a high voltage output from a low voltage input. The operating voltage for commercially available PV modules is low voltage dc, typically around 20 volts direct current (VDC) [11]. However, a high input voltage is necessary for efficient conversion to alternating current (AC) when using a DC-AC inverter. One option is to increase this voltage through series combination of multiple PV modules.

IV. PROBLEM DEFINITION

Since, the presence of random as well as intermittent nature of the sources which are also renewable seems to create some of the challenges which can be seen as technical issues.

1. Problems Concerned with Power Quality

As the inexhaustible DG's are incorporated through a force electronic converter to the framework they for the most part infuse sounds into the framework. Music are brought about by the exchanging system of the force electronic switches in the inverter which produce low quality of capacity to be provided to the clients. Henceforth, delicate exchanging control plans of the inverter ought to be acquainted with defeat the music. Dynamic or latent channels can likewise be utilized for the equivalent.

2. Storage

Because of the fuse of inexhaustible or PV source in the network power way stream, the norm of the lattice descends. The network may go about as a source or sink of intensity in agreement to the force produced from the photovoltaic (PV). In the event that the PV power age is overflow or if there should be an occurrence of a feeble lattice, battery can be settled on as a decision of putting away the abundance power. Be that as it may, acquainting a battery with the lattice associated PV frameworks welcomes issues of measuring and battery current and voltage control.

3. Protection Issues

Customary force frameworks are secured by overcurrent/overvoltage transfers and circuit breakers. However, as energy transformation frameworks (sun oriented) are presented the security of the system turns out to be more intricate. The issues of modification in the short out level, absence of continued issue current and converse force stream perseveres.

4. Short Circuit Level Change

Short out Level Change The short out level is a significant structure boundary in the plan of defensive gadgets, for example, circuit breakers and transfers. This is typically portrayed by the equal framework impedance at the shortcoming point and demonstrates the measure of fault current for the hand-off to follow up on the issue. The comparable impedance doesn't differ with the matrix controlled system frameworks, yet shifts with the DG arrange frameworks as the info changes to it changes momentarily.

V. PROPOSED METHODOLOGY

In this section an overview of the proposed methodology is given which is based on the decision tree classfier.

Algorithm Flowchart: in this section flowchart of the proposed algorithm is shown below

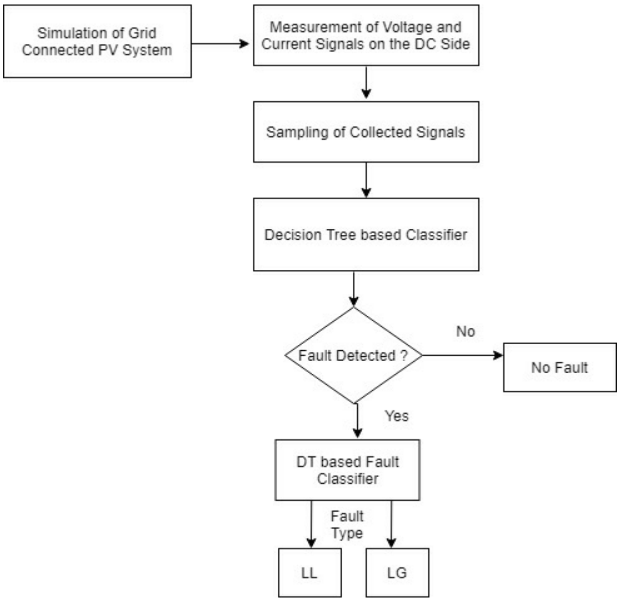

Figure 2: Flowchart of the proposed algorithm.

Working of proposed algorithm-

Step 1: is the configuration of the grid-connected PV generation system. PV array is connected to the DC bus via a DC/DC boost converter, and then to the AC grid via a DC/AC inverter.

Step 2: The DT is classification tree (CT) if the target is a discrete class, while it is regression tree (RT) if the target is a continuous value. The vector of predictors can be composed of both numerical variables (e.g. A) and categorical variables (e.g. B).

Step 3: In this step the fault will get detected then the function call will move to the DT based fault classifier and then the type of fault will classify with it as-LL, LG.

Step 4: Exit

VI. SIMULATION SETUP

For the Experimental simulation, the Classification stage has been validated using MATLAB simulation. The MATLAB code was developed using the MATLAB m-file editor toolbox. The test results and performance of the fault algorithm are shown in the following below sections.

PARAMETERS USED

The model is able to analyze the variation of PV parameters such as the ideality factor , Series resistance, thermal voltage and Band gap energy of the PV module with temperature as well as time. Finally a novel intelligent method based on Probabilistic Neural Network for fault detection and classification for PV farm with string inverter technology is proposed.

RESULT ANALYSIS

In this section the outputs obtained at different stages is given-

Table 1: Comparative study of power and voltage at different temperatures.

	0-60	60-120	120-160
Current (A)	6000	6000	5999
Power (W)	4	7	8

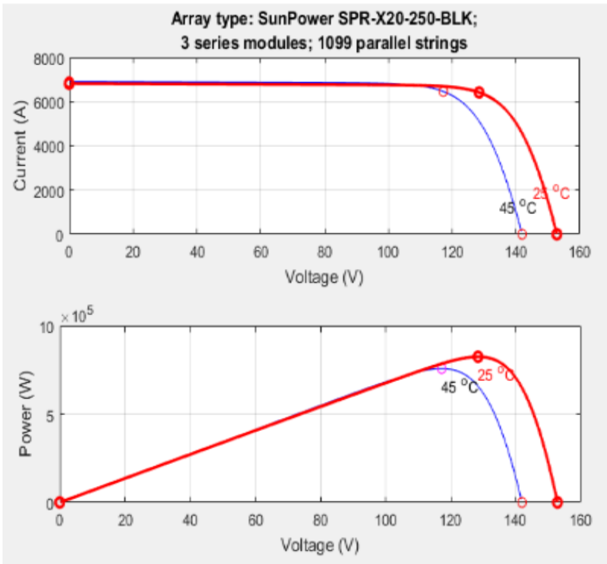

Figure 3: I-V and P-V characteristics of the array at different temperatures.

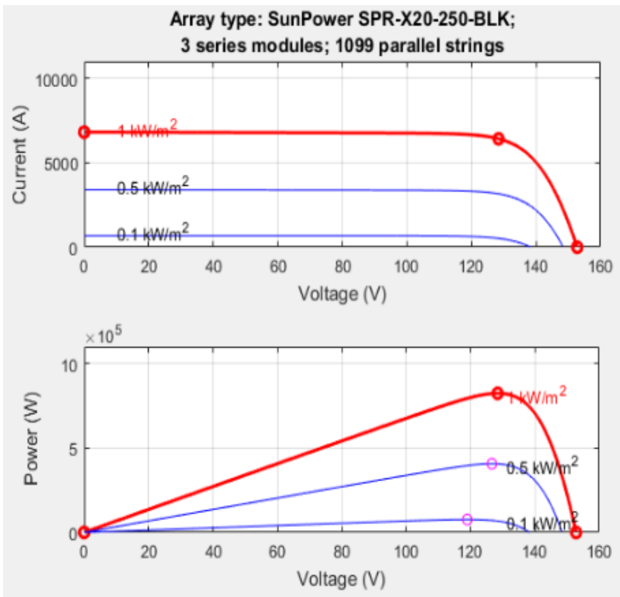

Figure 4: I-V and P-V characteristics of the array at different irradiance levels.

In the above figure 3 the graphical representation of the I-V and P-V characteristics of the array at different temperatures is shown. In the first graph the voltage is graphed from 0-160 V and current from 1-8000 in which the values of current obtained at 7000A . In the second graph the voltage is taken from 0-160 V and power is from $(0\text{-}10)*10^5$ in which the values of current obtained at 8 W/m^2

In the above figure 4 the graphical representation of the I-V and P-V characteristics of the array at different irradiances levels is shown. The voltage is graphed from 0-160 V and current from 1-10000 in which the values of current obtained at 0.1 kW/m^2, 0.5 kW/m^2, 1 kW/m^2.In the second graph the voltage is taken from 0-160 V and power is from $(0\text{-}10)*10^5$ in which the values of current obtained at 0.1 kW/m^2, 0.5 kW/m^2, 1 kW/m^2

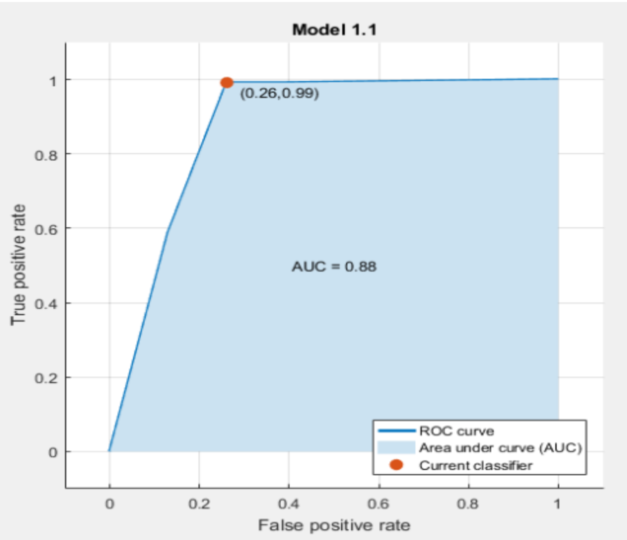

Figure 5: ROC curve for PP class

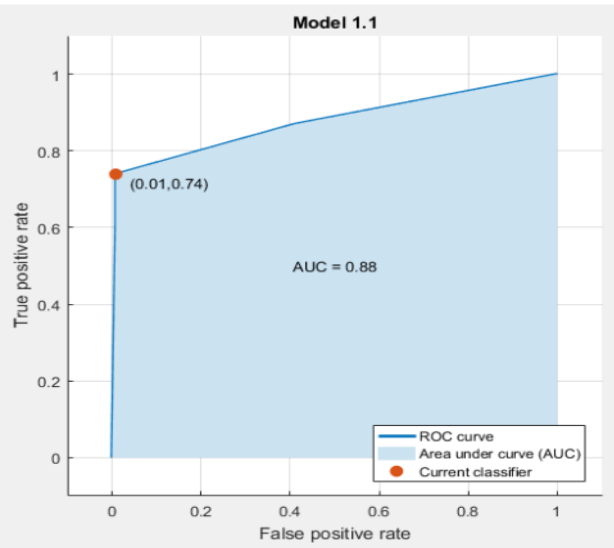

Figure 6: ROC Curve for PG Class.

In the above figure 5 the graphical representation of the ROC curve for PP class is shown in which the false positive values are graphed from 0-1 same as true positive values are from 0-1. In the above graph the current classifier is obtained at the ordinates at 0.26, 0.99 and the area under curve is obtained at 0.88.

In the above figure 6 the ROC Curve for PG Class is shown in which the false positive values are graphed from 0-1 same as true positive values are from 0-1. In the above graph the current classifier is obtained at the ordinates at 0.01, 0.74 and the area under curve is obtained at 0.88.

VII. CONCLUSION & FUTURE WORK

The literature of this paper gives a decent beginning stage to scientists and makers who are taking a shot at this field. The examination of the proposed techniques plainly denotes the contrasts between the different deficiency recognition strategies proposed by the different creators. The trial results on displaying the PV board from makers information sheet show that, it very well may be utilized to demonstrate any sun based module through programming. The outcomes from the fault location technique likewise reason that it very well may be utilized for distinguishing Open Circuits and Line-Line shortcomings for framework associated PV system. Because of the absence of accessibility of sun based boards, or real PV framework trial approval has not been finished. An augmentation of this examination can be trial approval. Likewise when more class characteristics, for example, 25% module open circuit or 1 board open circuit was recreated the grouping exactness was decreased to a mean of 82 %, since 25 % module open circuit covered with typical activity information. The incomplete shading discovery calculation was additionally not tentatively approved however the basic strategy and its application defense for network associated PV frameworks ought to permit it to precisely be arranged when there is an event of such kind of shading.

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