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Fault Detection in photovoltaic system by using wavelet transform and fuzzy logic

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Abstract

Photovoltaic technology is experiencing a rapid growth over the past few years. But abnormal conditions such as faults, low irradiance etc. lead to the reduction in the available output power from a photovoltaic array. To ensure performance and safety of the PV system, it is necessary to develop techniques that can efficiently localize the faults occurred. This paper presents a detection scheme for faults in the PV array. Such faults remain undetected under low irradiance conditions, particularly, when a maximum power point tracking algorithm is in service. If undetected, these faults can considerably lower the output of solar systems, damage the panels, and potentially cause fire hazards. The presented fault detection scheme employs discrete Wavelet Transform (DWT) technique and K-Nearest Neighbor (KNN) to classify the fault and determine its location. Simulation results verify the accuracy, reliability and scalability of the presented scheme.

Keywords— *KNN, Fuzzy Logic, DWT, fault detection*

I.INTRODUCTION

Demand of PV power plants is increasing day by day due to their advantages such as long life of PV panel, easy maintenance, off-grid installation, and ability to connect to utility grid which have portrayed a bright future for the use of PV system in the world. Since magnitude of fault current is much lower, the immediate impact of the fault might be minimal, making it difficult to be detected. Moreover, faults that occur under low irradiance, such as in cloudy days or mornings/evenings, might not be able to activate protection devices. Hence the designed fault detection strategies must be able to diagnose and clear such faults to enhance the reliability and efficiency of solar power plants.PV array output can be increased by improving the efficiency of the PV modules. Use of better material is one way of improving efficiency. Another way is to ensure that the array operates at optimal output conditions at all time. PV arrays once installed are expected to operate with minimal human intervention. They perform below optimum output power levels due to faults in modules, wiring, inverter, and so on. Most of these faults remain undetected over a long period of time resulting in loss of power. Technicians sent to locate and fix the faults within an array need to take time consuming field measurements. So, enquiries for lower cost and high efficiency-devices motivate the researchers to increase the reliability of PV system.

Power generation based on photovoltaic sources has gradually become an increasingly larger source of power generation during the last few decades. This trend has been matched with research into more efficient solar panels. Efficiency is measured as the ratio of incoming sun energy to the maximum attainable output power, with the current record being an efficiency of 44.7%. In addition to research into solar panels there is also an established interest in the surrounding equipment. Part of these systems is power inverters converting dc energy from the solar panels to the ac grid output. The efficiency concerns of solar panels naturally extend throughout the system, since any losses will affect the final efficiency of the complete system. Recently the area of photovoltaic (PV) inverters has progressed to distributed systems of inverters where a small inverter module is connected to every panel. 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 SURVEY

In this work, an astute framework for programmed recognition of blame in PV fields is proposed. This framework depends on a Takagi-Sugeno-Kahn Fuzzy Rule-Based System (TSK-FRBS), which gives an estimation of the moment control generation of the PV field in ordinary working, i.e., when no issues happen. At that point, the evaluated power is contrasted and the genuine power and a caution flag are produced if the distinction between forces beats an edge. The TSK-FRBS has been prepared utilizing information gathered from a PV plant test system, amid ordinary working. Starter tests were completed in a mimicked structure, by repeating both typical and blame conditions. Results demonstrate that the framework can perceive over 90% of blame conditions, notwithstanding when boisterous information is presented. [1]

The analysis and observing of PV frameworks are vital to limit the blackout time frame and amplify the lifetime yield. The goal of this exploration is to build up the disappointment recognition advances for PV frameworks which can be incorporated into the power conditioners. There are some disappointment location techniques, for example, warm strategies, visual techniques, and electrical techniques. Between these strategies, the electrical techniques appear to be the most fitting to coordinate into the power conditioners. To decide the situation of the fizzled module in PV cluster, the time space reflectometry (TDR) is the most encouraging in electrical disappointment discovery techniques. In TDR strategy, the inputted motion into PV cell/module/string and the reflected flag from the circuit are analyzed. The flag delay and the difference in waveform shape are converted into the disappointment position in the line and the sort of disappointment. In our principal tries under the dim conditions, the line length of a few cells string and the line length of a module in which numerous phones are associated in arrangement could be identified by TDR. These outcomes demonstrate the likelihood that TDR can locate the electrical property changes of PV modules and can be utilized for disappointment discovery technique. In view of these key analyses, the nitty gritty finding techniques ought to be considered in more profundity for their acknowledgment into power conditioners or test gear. [2]

Two strategies for the blame area in PV module string were tentatively contemplated. One was the earth capacitance estimation (ECM) and the other was the time-space reflectometry (TDR). By ECM, the separation position in the string was evaluated by the earth capacitance esteem without the impacts of the irradiance change, and the estimation blunder was little enough to decide the detachment position in real fix/support activity. Then again, TDR could recognize the debasement (arrangement opposition increment) and the situations in the string by the difference accordingly waveform. [3]

Little lattice associated photovoltaic frameworks up to 5 kWp are regularly not checked in light of the fact that best in class reconnaissance frameworks are not sparing. Consequently, some framework disappointments which prompt fractional vitality misfortunes remain unnoticed for quite a while. Indeed, even a disappointment those outcomes in a bigger vitality shortage can be hard to distinguish by PV laymen because of the fluctuating vitality yields. Inside the EU venture PVSAT-2, a completely robotized execution check has been created to guarantee greatest vitality yields and to upgrade framework support for little network associated PV frameworks. The point is the early location of framework glitches and changing working conditions to forestall vitality and consequent budgetary misfortunes for the administrator. The created methodology depends on satellite-determined sun based irradiance data that replaces nearby estimations. Related to a reproduction show the normal vitality yield of a PV framework is figured. In the event of the event of a characterized distinction between the mimicked and genuine vitality yield, a computerized disappointment discovery routine scans for the most likely disappointment sources and tells the administrator. This paper depicts the individual segments of the created methodology—the satellite-inferred irradiance, the utilized PV recreation demonstrate, and the standards of the mechanized disappointment recognition schedule. In addition, it presents consequences of a 8-months test stage with 100 PV frameworks in three European nations. [4]

A blame location framework in PV framework has been created. The exactness of PV module blame identification utilizing AC yield information in the PV framework is talked about. In the first place, the yield attributes in a broken PV cluster were dictated by utilizing a blame recreation PV framework. Second, the accompanying three blame identification strategies were producedComparison of estimated yield esteem and evaluated esteem got from estimated illumination. Strategy 2: Comparison of present and past execution proportions (PRs). Technique 3:

Comparison of present and past yield contrasts in an intersystem. Third, the blame recognition precision in the proposed strategies was assessed based on the test results. [5]

This paper shows the advancement of a viable blame identification approach in photovoltaic (PV) frameworks, expected for online execution. The methodology was created and approved utilizing field estimations from a Canadian PV framework. It has a genuinely low level of multifaceted nature, yet accomplishes a high blame location rate and can effectively adapt to variations from the norm present, all things considered, estimations. The blame discovery depends on the correlation between the deliberate and model forecast consequences of the air conditioner control generation. The model gauges the air conditioner control generation utilizing sun based irradiance and PV board temperature estimations. Preceding model improvement, an information investigation technique was utilized to recognize esteems not agent of an ordinary PV framework activity. The first 10-min estimations were found the middle value of over 1h, and both datasets were utilized for demonstrating. With the end goal to all the more likely speak to the PV framework execution at various daylight levels, models for various irradiance ranges were created. The outcomes uncover that the models dependent on hourly midpoints are more precise than the models utilizing 10-min estimations, and the models for various irradiance interims prompt a blame discovery rate more noteworthy than 90%. The PV framework execution proportion (PR) was utilized to monitor the framework's long haul execution. [6]

In this work, we present another programmed supervision and blame discovery technique for PV frameworks, in view of the power misfortunes examination. This programmed supervision framework has been created in MATLAB&Simulink condition. It incorporates parameter extraction methods to ascertain fundamental PV framework parameters from observing information in genuine states of work, considering the ecological irradiance and module temperature development, permitting recreation of the PV framework conduct progressively. The programmed supervision technique investigations the yield control misfortunes, introduces in the DC side of the PV generator, catch misfortunes. Two new power misfortunes markers are characterized: warm catch misfortunes (Lct) and various catch misfortunes (Lcm). The handling of these pointers enables the supervision framework to create a defective flag as marker of blame identification in the PV framework task. Two new pointers of the deviation of the DC factors regard to the mimicked ones have been likewise characterized. These markers are the current and voltage proportions: RC and RV. Investigating both, the defective flag and the current/voltage proportions, the sort of blame can be distinguished. The programmed supervision framework has been effectively tried tentatively. [7]

This paper shows an itemized methodology for programmed supervision, blame discovery, and determination of conceivable disappointment sources prompting aggregate or fractional loss of profitability in framework associated PV frameworks. The symptomatic methodology is a piece of the checking framework permitting, in the meantime, displaying and reproduction of the entire framework and factors estimations progressively. The blame discovery calculation depends on the correlation of mimicked and estimated yields by breaking down the misfortunes present in the framework while the recognizable proof of the sort of blame is completed by dissecting and looking at the measure of mistakes deviation of both DC current and voltage as for an arrangement of blunders limits assessed based on free blame framework. The proposed strategy has been approved in with exploratory information in a framework associated PV framework in the Center de Development des Energies Renouvelables (CDER) in Algeria. [8]

Photovoltaic (PV) framework execution can be corrupted by a progression of variables influencing the PV generator, for example, fractional shadows, ruining, expanded arrangement opposition and shunting of the cells. This worry has prompted more noteworthy enthusiasm for enhancing PV framework activity and accessibility through programmed supervision and condition checking of the PV framework segments, particularly for little PV establishments, where no specific work force is available at the site. This work proposes a PV exhibit condition checking framework dependent on a PV cluster execution show. The framework is parameterized web based, utilizing relapse displaying, from PV cluster generation, plane-of-exhibit irradiance, and module temperature estimations, procured amid an underlying learning period of the framework. After the model has been parameterized consequently, the condition observing framework enters the typical activity stage, where the execution demonstrates is utilized to anticipate the power yield of the PV cluster. Using the anticipated and estimated PV cluster yield control esteems, the condition observing framework can recognize control misfortunes above 5%, happening in the PV exhibit. [9]

In this paper, we propose a photovoltaic (PV) vitality transformation framework (PVECS) blame recognition conspire utilizing a fragmentary request shading connection classifier in micro-distribution frameworks. In light of electrical examination strategy, yield control debasement is utilized to screen physical conditions with changes in a PV exhibit's hardware, including grounded flaws, jumble issues, crossed over deficiencies between two PV boards, and open-circuit issues. The PV exhibit control relies upon sun based radiation and temperature, and greatest power point following (MPPT) control is utilized to keep up stable power supply to a micro-distribution framework in case of a blame in the PVECS. The MPPT calculation is utilized to gauge the coveted most extreme power, which is then contrasted and the meter-perused control. Partial request dynamic mistakes are resolved to measure yield control debasement between the coveted most extreme power and the meter-perused control. At that point, a shading connection investigation is utilized to isolate typical conditions from blame occasions. For a PVECS with two boards in parallel, the re-enactment results exhibit that the proposed technique is appropriate for on-going applications and is adaptable for blame distinguishing proof. Its identification rates surpassed 88.23% for six occasions. [10]

III.SYSTEM ARCHITECTURE

The objective of imparting protection to the micro grid is to ensure accuracy and reliability in the detection and classification of fault for immediate isolation of faulty feeder. Keeping this in mind, a discrete wavelet transform and kNN-based fault detector/classifier have been devised and presented in the paper which can perform efficiently under intermittent nature of PVDG and nonlinearity in the load as well.

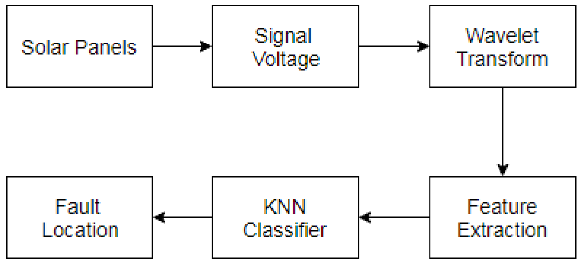

Fig 3.block diagram of proposed system

3.1. Pre-processing of Signal and Feature Extraction:

Wavelet transform is very dominant and versatile tool to analyze and record the pattern obtained due to any disturbance or fault occurred in the system. The advantage of wavelet transform over Fourier transform lies in the fact that latter can be utilized to analyze the signal only in the frequency domain. So, wavelet transform is considered better than Fourier transform. Wavelet transform split the signal into different scales corresponding to distinct frequency patterns through translation (shift in time) and dilation (compression in time) of mother wavelet.

The mother wavelet can be described by following equation:

$$\emptyset_{jk}(t) = 2^{-j/2}\phi\left(2^{-j}t - k\right)$$

Signal is analyzed by wavelets through multi-resolution technique at distinct resolution and frequencies. The decomposition of input signal x (n) through low-pass Butterworth filter is carried out by the following equation:

$$y_{\text{low}}[k] = \sum x[n].h[2k - n]$$

Where Ylow[k] is the output of low-pass filter h[n] obtained after down sampling by 2. A total number of 6 features including B1 bus voltage and current in section S1 for all the three phases A, B and C have been considered for feature extraction process.

3.2. Error determination using Fuzzy logic

Design of a controller is based on an assumed mathematical model that resembles a real system. The error between actual system and its mathematical representation is calculated and if it is relatively insignificant than the model is assumed to work effectively. A threshold constant that sets a boundary for the effectiveness of a controller also exists. The control input is fed into both the real system and mathematical model. Here, assume x(t) is the output of the real system and y(t) is the output of the mathematical model. Then the error □ (t) can be calculated as follows −

$$\epsilon(t) = x(t) - y(t)$$

Here, x desired is the output we want from the system and μ (t) is the output coming from controller and going to both real as well as mathematical model.

3.3. Fault location using kNN:

Pre-processing and feature extraction are followed by the development of kNN-based technique for performing the required task of fault detection/classification separately under both modes of micro grid operation. kNN algorithm is very simple and widely known among all the other pattern recognition techniques due to its flexible decision boundaries. It exhibits lazy learning approach; i.e. it imparts negligibly less effort at the time of training and exceptionally full effort during the prediction. The k-nearest neighbor performs the classification task on the basis of similarity index by taking into account the distance measure in which ‘k’ refers to the integer value mostly lying in the range of 3–10. It is preferred to choose odd value of k to avoid the situations of tie during the prediction of any class. Any particular class among all available input classes is predicted as the output by kNN on the basis of majority votes casted by the neighboring points corresponding to the nearer class. For any test case X, the probability of the case belonging to the class Ci should be maximum as given by the equation:

$$\mathrm{kNN}(X) = \max p\,(C_i, X)$$

For performing the task of classification, weights are given to the neighbours in such a way that the nearer neighbours add up to more weights to the average than that of the farther one. Weights are assigned to the nearest neighbours on the basis of Euclidean distance calculated using the following equation:

$$d\,(x,t) = \sqrt{(x_1 - t_1)^2 + (x_2 - t_2)^2 + \cdots + \left(x_p - t_p\right)^2} = \sqrt{\sum_{i=1}^{p} (x_i - t_i)^2}$$

The kNN algorithm-based protection technique performs the task of fault detection and classification under grid-connected and islanded mode separately.

IV.ALGORITHM

The different steps **of** the proposed scheme can be sketched as follows:

Step 1. Voltage and current signals are retrieved at bus B1 by creating the fault scenarios with variation in fault parameters such as fault resistance (0–100), inception angle (0° to 90°) and fault location (0–20 km).

Step 2. The signal obtained in step 1 is pre-processed through low-pass Butterworth filter at the cut-off frequency of 480 Hz.

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Step 3. The processed signal is sampled with sampling frequency of 1.2 kHz.

Step 4. The approximate coefficients are extracted through discrete wavelet transform (DWT) using db3 wavelets up to third level of decomposition and standard deviation is obtained which is further fed as the input feature for fuzzy logic.

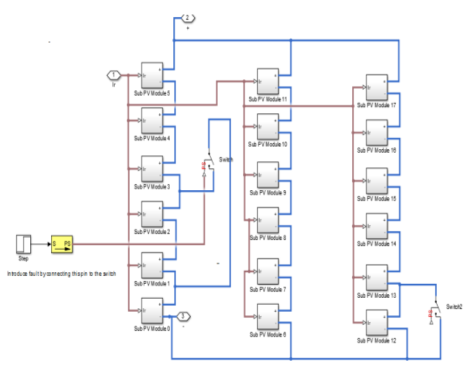
Step 5. Output of fuzzy logic which determine error in PV cells, is fed as input to KNN for determining location of Error.

Step 6. Select the number of nearest neighbours and train the dataset using kNN.

Step 7. Any fault sample is tested through the trained network and depending on the output of respective kNN, the relay trip signal is generated to the respective breaker for isolation of faulty phase in the network.

V.RESULT

Simulation result of grid connected photo voltaic system is shown in following fig.



The faults that usually occur on the DC side of PV arrays and the challenges of detecting such faults. The simulation studies demonstrate the performance of the detection algorithm under such fault cases. Numerous scenarios have been carried out, which include combinations of different environment temperatures, irradiance levels, fault instants, fault impedances, and LL and LG faults at different mismatch degrees.

1] LG Fault- LG faults are simulated where the scenarios and corresponding parameters are similar to those of LL faults. Following fig 5.2 shows the line to ground fault in PV system.

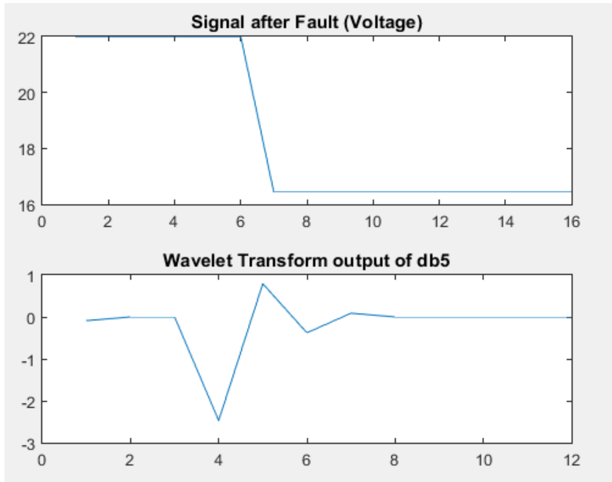


Fig5.2 Line to ground fault

2] LL Fault- LL faults are simulated under different conditions. These conditions are the combinations of different operation temperatures (5, 15, 25, 30, 40, and 50◦C), different irradiance levels (300, 500, and 1000W/m2), line to-the-same-line and line-to-different-line faults, mismatch percentage (from 10% to 60% with an increment of 10%), fault impedances (0, 5, 15 and 25), and different fault inception instants including positive and negative peaks of the grid phase. Fig 4.3 shows the line to line fault in PV system.

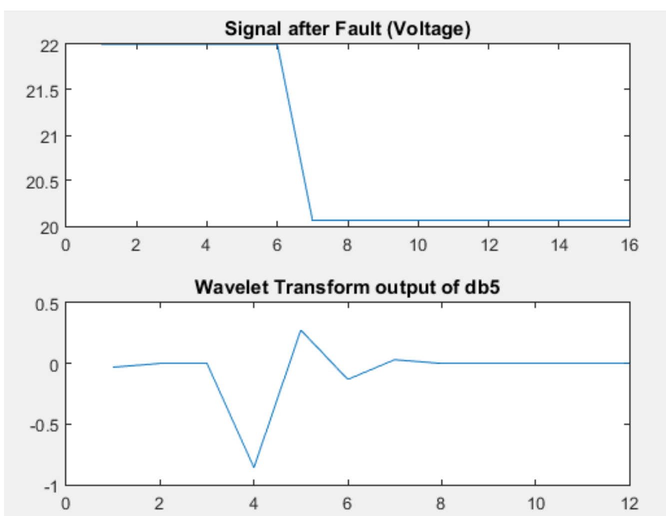


Fig: 5.3 Line to Line Fault

VI. CONCLUSION

The growing penetration of distributed energy resources(DERs) in modern power distribution networks operating as micro grid poses a great challenge for the conventional protection scheme due to significant variation in the fault current levels under the grid-connected and islanded mode of operation. In this regard, this paper has devised an efficient protection scheme based on discrete wavelet transform (DWT) and k-nearest neighbor (kNN) for fault detection/classification implemented for dual modes of micro grid operation considering the photovoltaic PV source and nonlinearity in the load. The input features containing the standard deviation of approximate coefficients of voltage and current signal at the relaying bus are obtained through pre-processing of the signals by DWT. The features so obtained are fed as input to train the kNN-based classifier to accomplish the task of fault detection/classification pre-processing of the signals by DWT. The features so obtained are fed as input to train the kNN-based classifier to accomplish the task of fault detection/classification successfully. The proposed scheme has not been influenced by nonlinearity in the load and intermittency of the PV source. Fuzzy logic is used for determine error and location of error is determine using KNN algorithm.

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