Novel Scheme for Fault Diagonosis in PV Modules in Grid Connected Mode

[1]Rohit Pal, [2]Abhishek Dubey, [3]Pawan Kumar Sandaliya

[1]PG Scholar, [2]Professor, [3]Assistant Professor

[1,2,3]Department of Electrical and Electronics Engineering, Bhopal Institute of Technology & Science Bhopal,India

Abstract: The PV systems has emerged as popular alternative in contrast to conventional resources used in production of an electrical energy. The solar energy is available in abundance and owing to simplicity of PV system it can be installed almost anywhere where as the other renewable energy resources are unevenly spread over the wide geographical area. The small operating and maintenance cost of the PV system enables the user to recover the investment cost and reduce the payback time period after the installation of the system. It has also significantly reduced the carbon footprint during the process of the production of the electricity. The only disadvantage of PV system is that efficiency of conversion of solar energy into electrical energy is still not good. The recent research is focused on enhancing the efficiency using different materials in fabrication of solar panels. Apart from this the emphasis is on increasing the efficiency of the operation of the system. It is equally important to reduce the downtime of the system due to occurrence of the faults. To achive this objective a method is needed that can detect, classify, locate and clear the fault swiftly. This paper presents the state of art on such techniques that can be employed for fault detection and diagonosis.

Keywords—Detection, Classification, Reflectometery, Fault Diagnosis, Protection System, PV Systems, Support Vector Machine, k- Nearest NeigbourAlogorithm

I. INTRODUCTION

In an oder to meet the deficit between the generation of electrical increasing and exponentially rising demand for it, the role of PV systems has become pivotal as they can be put into operation anywhere. These systems has an ability to work in islanded mode catering the local demand & can be easily inefratedwoth main utility grid in an order to meet the demand that may arise over wide gepgraphical area. The design & architecture of PV systems are not complicated & hence the cost realated to its operation is almost negliglble. However these systems suffers from the major drawback of poor efficiency of the solar panels which is measured as the ratio of input solar energy to the output power of the panels. This efficiency is around 45% .The unpredictable & variable changes in the climate duirng the operation of the PV systems affects the efficiency of power generation [2,3].The loss of energy occurs in the PV system due to various faults occurring in it such as faults due to short circuit, open circuit, and unavoidable faults such as shading and ageing of the panel. This may also raise the safety concerns. If these faults go unnoticed it may hamper the efficiency of the system drastically. For detection of such faults a principle of thermal infrared detection is used which is based on the fact that whenever the faults occurs in the solar panels it results in to loss in form of heat & this cuases the heating of panels. The rise in temperature can be detected with the help of the thermal scanner.

In an order to improve the overall efficiency of the system it is important to improve the efficiency of the components of the system such as power electronics converters, battery chargers, batteries and the operation of the system. For this it is needed to detect the hidden faults in the system & classify them so that suitable protect scheme can be pressed into action in an order to clear the faults & avoid the occurrence of such faults in the future.In recent times various fault detection & diagnosis scheme has been proposed that uses the machine learning and artificial intelligence techniques. Common to all these methods is the collection of information related to the voltages & currents by measureing them at various locations of the system. These sampled signals are used to form the data base for learining. Then data mining technique is used to identify the hidden patterns in the learining data base which is further utilized in classification of information. At the end this information helps in taking decision of regarding control action & protection scheme which may be in form of suggestions or automated actions.

II. LITERATUE REVIEW

A. Y. Appiah et al [5] had presented elaborated review on different methods of fault identification and diagnosis. They have delineated four major faults and their possible causes as ground fault, line to line fault, arc fault and hot spot faults. Then they have considered the conventional&contemporarytechniques for fault detection and diagnosis (FDD) used in monitoring of faults. Finally they proposed the single assessment matrix that examines the performances of the modern FDD methods and suggested recommendations wbased on the same.

A.Mellit et al [12] reviewed diverse category of faults& their causesoccuring in the PV system and various fault

detection and diagnosis (FDD) methods that can be used to clear them. Then they underlinedvarious advantages and disadvantages related to different FDDs.

V.S.B Kurukuru et al [1] illustrated the significance of fault analysis and its classification in PV systems that results into the improved stability & operation of system. They have anticipated the novel algorithm bsed on the feature extraction capability of wavelet transform and classification behaviour of RBFNs for classification of fault.The dynamic fusion of the kernels have been used to enhance performance of the proposed classifier. They have tested the proposed model ofsingle phase 1 kW standalone PV system and they have observed the training efficiency of 100% under 13 s and 97% under 0.2 s respectively.

M. Muttilo et al [2] focused on the evaluationof efficiencyreduction in PV system due to occurrence of faults and thereby reducing the outpu. The most complexjob is to curtail the time needed to assess the efficiency which can be obtained by analyzing various electrical parameters based on information gathered from modules. To achieve the said objective thermographic inspection can be carried out. The author offered the method that emphasizes on associating the thermal images of the panels with their efficicency.This helps in identifying the fault and relatedlosses without hampering the operation of PV system. MATLAB is used to simulatethe PV systemandin determination of its ideal, practical I-V characteristics & efficiency. Then based on open circuit, short circuit and maximum power pointtopology of fault is determined. The overall health is estimated by compairing the electrical parameters with thethermal images taken while PV system is in operation.

Natsheh, E. et al [3] established factors such as the magnitude of solar radiations reaching to panel, temperature, shading etc affects the output of the solar panels. They devisedthe novel technique based on tree like hierarchy that employs fuzzy non linear auto regressive network with exogenous inputs in automatic fault detection and diagonosis.

According to Basnet B et al [4] ther may occur a false presiction of faults in the system as I/V characteristics of PV system in winter season have similarity to I/V characteristics during healthy state of the operation. To avoid this problem they recommend the fault diagnosis method that employs the database generated by gathering the information under normal and fault conditionsoccurigin winter season. Then data mining techniqueisused to normalize and pre process the database before putting it as an input to train the probabilistic neural network (PNN). When PNN fetches new data it predicts and classify the faults. Masoud Alajmi et al [9] usedthe voltage and current sensors in detection, localization and classifications of the common faults alongwith the machine learning. Siva Ramakrishna Madeti et al presented string level fault detection and diagnosis method which is based on k-nearest neighbors. They also utilized the manufacture's datasheet provided for standard testing condition and normal operating cell temperature to develope the extensive model of the PV system that precisely traces the I/V characteristics under different irradiance and temperature magnitudes. In contrast to this method A. Haque et al. [6] discussed the difficulties and constraintlinkedto faultsdiagonosis in PV system.They also elaborated the detailed analysis of the faults accountable for failure of solar module. Then they developed the supervising tool based on thermography and artificial intelligence (AI) that can detectvariety of faults and filter out the insignificant inconsistencyat the same time. It uses the multilayer preceptor (MLP) networks for classifying the fault and determining its its location by employing the neural network (NN) classifier to the transfer characteristics of the faulty module, then feature extraction is carried out with the help of discrete wavelet transform (DWT) that reduces the NN input. The devised algorithm is competent for round the clock surveillance in automated fashion.

FouziHarrou et al [15] detailed the approach based on statistics that have an advantages of the one diode model and the exponentially weighted moving average (EWMA) for detection and classification fault at the DC side of the PV systems. The array of the residuals of the current, voltage and power is prepared by measuring the temperature & irradiance levels which is further utilised in determining the inequality between measured and the predictedvalues for the Maximum Power Point (MPP) and then use this as an indicators of the faults. Then multivariate EWMA is applied to these residuals for detecting the faults but it does not give any information about the fault type which is further identified by applying univariate EWMA chart. The issue of superfluous alarms &unidentified fault detection due statistical failure can be avoided by employing multi scale representation to generalized likelihood ratio test (GLRT) and considering its nature variance [16]. MS-WGLRT is evaluated based on measured and simulated data of PV system. It is then used to prepare the chart in an order to detect single and multiple failures.

Mahmoud Dhimish et al [34] presented the method in which the standard operation of PV systems is simulated and statistical analysis is carried out on data measured in the PV system. The statistical *t*-test is used in comparing the theoretical and practical output power and which is then utilised as an fault indicator. The the location of the fault is determined by calculating the ratio between the measured and theoretical DC power and voltage. The

method is proficientin detecting multiple faults categorized under eight different fault types on multiple strings. Statistical analysis is used to deterine whether the output of the PV modules is affected by cracks on the solar panelsElectroluminescence is observed continuously for detecting the possible faults in such scenarios [29].

In this paper [20] author proposed a strategy that take account of the faults based on multi class bolster vector machine (SVM)analysis through online calculation. Reproduction models are used to represent the photovoltaic modules and are implement to examine the line-to-line deficiency and unpredicted corruption faults. Ali, M. H. et al [21] presentteda method for systematic observation and summarizingthe deficiencies pragmatic in PV systems framework. The proposed strategy is based on evaluation carried out with the help of analysis of meticulous differential buildupin relation with faulty photovoltaic module and its accurate model.

Karim, I. A. et al [37] evaluated the reduction in the efficiency due to faults associated with Solar PV cell and modules. They pointed out the disadvantages of fossil fuels to be used in production of electricity and numerous advantages of implementing renewable energy sources for sustainable production of electrical energy.

Table 1: Summary of Computational Methods.

Authors	Methods	Purpose	Tasks
V.S.B Kurukuru [1]	Feature extraction competence of wavelet transform and classification traits of RBFNs	Fault detection & diagnosis	Enhancement in stability & operation of PV system
M. Muttilo [2]	Thermographic inspection	Identification of fault and losses without disturbing the operation of PV system	Analysis of the efficiency drop in PV system due to faults
Elyes Garoudja [20]	Exponentially weighted moving average (EWMA)	Early fault detection	Detection of faults at DC side of the system due to shading of PV modules
Siva Ramakrishna Madeti [14]	k-nearest neighbors rule	Classification and detection of faults on real time basis	Open circuit, L-L faults, partial shading of PV modules considering both cases of bypass diode presence and absence and faults due partial shading considering inverted bypass diode
FouziHarrou [15]	Univariate and multivariate EWMA	Detection & diagnosis of fault	Fault monitoring at the direct current side of the system
Majdi Mansouri [16]	Multi scale weighted generalized likelihood ratio test (MSWGLRT)	Monitoring & detection of Faults	Reduction in false alarm and missed identification rates
Kashyap, N., & Gautam, A. [23]	State machine model	Detection of fault in DC converter	Adherence to Peak Current Mode control procedure along with inordinate slope signal.
Mahmoud Dhimish [34]	Statistical *t*-test method	Detection of multiple fault on multiple array	To compare the measured and standard output power for indicating the faults.
A Grid Connected PV System Fault Diagnosis Method [35]	Nikolaos Sapountzoglou, Bertrand Raison/IEEE/ 2019	Creation of the fault signature table based on response of system to various fault scenarios	The fault diagnosis method generates alarm signal in 60 ms

III. PROBLEM DEFINITION

There are numerous faults that occurs in PV system remains hidden and go unnoticed. This may cause damage to PV system &ultimately affects the performance and efficiency of the PV system.It also raises safety & protection concernsin operation of PV system. It is

required to devise an universal method which can employed to perform the task of detection, location, classification, isolation and clearance of faults. The above said problem can have following objectives:

1. Classificationof various faults that may arise in a PV system and reveal the limitations of existing methods for fault detection and diagonosis.
2. To formulate the transmission line model for solar panels which can employ different refelectomery methods for infering faultsoccuring in PV system.

IV. CONCLUSION

The PV systems used in production of electrical energy offeres numerous advantages as compard to the other resources. They utilize the inexahautible source of energy available in abundance i.e. solar energy, these systems are simple in design, easy to operate and maintain apart from flexibility to integrate with main uitility grid. However when operated in online mode i.e. in grid connected mode they poses threats to the stability of the later.The dependence on the solar energy for the production of electrical energy give rise to intermittent output of the solar panels and this may lead to faults that may go unnoticed &results into catastrophic failure. This dissertation work is focused on identification, classification & rectification of the faults using machine learning.

REFERENCES

[1] V. S. B. Kurukuru, F. Blaabjerg, M. A. Khan, and A. Haque, “A novel fault classification approach for photovoltaic systems,” Energies, vol. 13, no. 2, p. 308, 2020.

[2] M. Muttilo, I. Nardi, V. Stornelli, T. de Rubeis, G. Pasqualoni, and D. Ambrosini, “On field infrared thermography sensing for PV system efficiency assessment: results and comparison with electrical models,” Sensors, vol. 20, no. 4, p. 1055, 2020.

[3] Natsheh, E.; Samara, S. Tree Search Fuzzy NARX Neural Network Fault Detection Technique for PV Systems with IoT Support. Electronics 2020, 9, 1087.

[4] Basnet, B.; Chun, H.; Bang, J. An Intelligent Fault Detection Model for Fault Detection in Photovoltaic Systems. J. Sens. 2020, 2020, 6960328.

[5] A. Y. Appiah, X. Zhang, B. B. K. Ayawli, and F. Kyeremeh, “Review and performance evaluation of photovoltaic array fault detection and diagnosis techniques,” International Journal of Photoenergy, vol. 2019, Article ID 6953530, 19 pages, 2019.

[6] A. Haque, K. V. S. Bharath, M. A. Khan, I. Khan, and Z. A. Jaffery, “Fault diagnosis of photovoltaic modules,” Energy Science & Engineering, vol. 7, pp. 622–644, 2019.

[7] D. S. Pillai, F. Blaabjerg, and N. Rajesekar, “A comparative evaluation of advanced fault detection approaches for PV systems,” IEEE Journal of Photovoltaics, vol. 9, no. 2, pp. 513–527, 2019.

[8] V. S. B. Kurukuru, A. Haque, M. A. Khan, and A. K. Tripathy, “Fault classification for photovoltaic modules using thermography and machine learning techniques2019 International Conference on Computer and Information Sciences (ICCIS),, Sakaka, Saudi Arabia, 2019.

[9] M. Alajmi, S. Aljahdali, S. Alsaheel, M. Fattah, and M. Alshehri, “Machine learning as an efficient diagnostic tool for fault detection and localization in solar photovoltaic arrays,” in Proceedings of 32nd International Conference on Computer Applications in Industry and Engineering, vol. 63, pp. 21–33, USA, 2019.

[10] A. F. Agarap, “Deep learning using rectified linear units (ReLU),” 2019, https://arxiv.org/abs/1803.08375

[11] Jaeger-Valdau, A. PV Status Report 2019; Technical Report November; Publications Office of the European Union: Luxembourg, 2019.

[12] A.Mellit, G.M.Tina, S.A.Kalogirou, Fault detection and diagnosis methods for photovoltaic systems: A review, Renewable and Sustainable Energy Reviews, vol. 91, pp. 1-17, August 2018

[13] Shibo Lu, B.T. Phung, Daming Zhang, A comprehensive review on DC arc faults and their diagnosis methods in photovoltaic systems, Renewable and Sustainable Energy Reviews, vol. 89, pp. 88-98, June 2018.

[14] Siva Ramakrishna Madeti, S.N.Singh, Modeling of PV system based on experimental data for fault detection using kNN method, Solar Energy, vol. 173, pp. 139-151, October 2018

[15] FouziHarrou, Ying Sun, Bilal Taghezouit, Ahmed Saidi, MohamedElkarimHamlati, Reliable fault detection and diagnosis of photovoltaic systems based on statistical monitoring approaches, Renewable Energy, vol. 116, Part A, pp. 22-37, February 2018

[16] Majdi Mansouri, Mansour Hajji, Mohamed Trabelsi, Mohamed Faouzi Harkat, Ayman Al-khazraji, Andreas Livera, Hazem Nounou, Mohamed Nounou, An effective statistical fault detection technique for grid connected photovoltaic systems based on an improved generalized likelihood ratio test, Energy, vol. 159, pp. 842-856, 15 September 2018

[17] Rabah Benkercha, Samir Moulahoum, Fault detection and diagnosis based on C4.5 decision tree algorithm for grid connected PV system, Solar Energy, vol. 173, pp. 610-634, October 2018

[18] Zhicong Chen, Lijun Wu, Shuying Cheng, Peijie Lin, Yue Wu, Wencheng Lin, Intelligent fault diagnosis of photovoltaic arrays based on optimized kernel extreme learning machine and I-V characteristics, Applied Energy, vol. 204, pp. 912-931, 15 October 2017

[19] AbhikHazra, Saborni Das, MousumiBasu, An efficient fault diagnosis method for PV systems following string current, Journal of Cleaner Production, vol. 154, pp. 220-232, 15 June 2017.

[20] Elyes Garoudjaa, FouziHarrou, Ying Sun Kamel Kara AissaChouderSantiago Silvestred, "Statistical fault detection in photovoltaic systems" Solar EnergyVolume 150, 1 July 2017, Pages 485-499

[21] L. Wang, J. Liu, X. Guo, Q. Yang and W. Yan, "Online fault diagnosis of photovoltaic modules based on multi-class support vector machine," 2017 Chinese Automation Congress (CAC), Jinan, China, 2017, pp. 4569-4574.

[22] Ali, M. H., Rabhi, A., El Hajjaji, A., & Tina, G. M. (2017). Real Time Fault Detection in Photovoltaic Systems. Energy Procedia, 111, 914-923.

[23] Dhimish, M., Holmes, V., Mehrdadi, B., & Dales, M. (2017). Simultaneous fault detection algorithm for grid-connected photovoltaic plants. IET Renewable Power Generation, 11(12), 1565-1575.

[24] Kashyap, N., & Gautam, A. (2017, March). Fault tolerant peak current mode controlled flyback converter for solar PV modules. In Power and Embedded Drive Control (ICPEDC), 2017 International Conference on (pp. 265-269). IEEE.

[25] Zhaohui Cen, "Modeling and simulation for an 8 kW three-phase grid connected photovoltaic power system", Open Physics, Vol.15, pp.603-612, 2017.

[26] Elyes Garoudja, FouziHarrou, Ying Sun, Kamel Kara, AissaChouder, Santiago Silvestre, Statistical fault detection in photovoltaic systems, Solar Energy, vol. 150, pp. 485-499, 1 July 2017

[27] Chinedu I.Ossai, Optimal renewable energy generation – Approaches for managing ageing assets mechanisms, Renewable and Sustainable Energy Reviews, vol. 72, pp. 269-280, May 2017

[28] Bechara Nehme, NacerK.Msirdi, Aziz Namaane, Tilda Akiki, Analysis and Characterization of Faults in PV Panels, Energy Procedia, vol. 111, pp. 1020-1029, March 2017

[29] Siva Ramakrishna Madeti, S.N.Singh, A comprehensive study on different types of faults and detection techniques for solar photovoltaic system, Solar Energy, vol. 158, pp. 161-185, December 2017

[30] Mahmoud Dhimish, Violeta Holmes, Bruce Mehrdadi, Mark Dales, The impact of cracks on photovoltaic power performance, Journal of Science: Advanced Materials and Devices, vol. 2, Issue 2, pp. 199- 209, June 2017

[31] M. Bressan, Y .El Basri, A. G. Galeano, C.Alonso, A shadow fault detection method based on the standard error analysis of I-V curves, Renewable Energy, vol. 99, pp. 1181-1190, December 2016

[32] He Wang, Ao Wang, Hong Yang, Jingsheng Huang, Study on the Thermal Stress Distribution of Crystalline Silicon Solar Cells in BIPV, Energy Procedia, vol. 88, pp. 429-435, June 2016

[33] Oussama Hachana, Giuseppe Marco Tina, Kamel EddineHemsas, PV array fault Diagnostic Technique for BIPV systems, Energy and Buildings, vol. 126, pp. 263-274, 15 August 2016

[34] Jack Flicker, Jay Johnson, Photovoltaic ground fault detection recommendations for array safety and operation, Solar Energy, vol. 140, pp. 34-50, 15 December 2016

[35] Nikolaos Sapountzoglou; Bertrand Raison, "A Grid Connected PV System Fault Diagnosis Method", IEEE International Conference on Industrial Technology (ICIT), 2019.