International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 03 | Mar 2019 www.irjet.net p-ISSN: 2395-0072

Fault Classification using Fuzzy for Grid Connected PV System

Shwetha G[1], B. Devi Vighneshwari[2]

[1]PG Scholar, Dept. of Electrical and Electronics Engineering, The Oxford College of Engineering, Karnataka, India.
[2]Associate Professor, Dept. of Electrical and Electronics Engineering, The Oxford College of Engineering, Karnataka, India.

Abstract - *A grid-connected PV power system is an electricity generating solar PV power system that is connected to the utility grid. They range from small residential and commercial rooftop systems to large utility-scale solar power stations. An integration of such distributed generations (DGs) to the utility grid has raised the need for good power quality, safety operation and islanding protection of the grid interconnection from fault. Fault is a common term associated with every type of electrical device under abnormal conditions. This Project presents the fault classification using fuzzy in a distributed generation, particularly photovoltaic 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 using fuzzy logic controller (FLC). Mainly the faults are identified as AC faults such as inverter side fault and DC fault such as fault in PV array and Dc link fault. A case study of a 100 kW array connected to a 25 kV grid via a DC-DC boost converter and a three-phase three-level Voltage Source Converter (VSC) system used to illustrate the proposed FLC control through MATLAB/Simulink software. The classification, simulation and discussion of all possible faults in both AC and DC side of PV system are presented.*

Key Words: **Fuzzy Logic Controller (FLC), Three-Phase Three Level Voltage Source Converter (VSC), DC-DC Boost Converter,25kV Grid, 100kW PV Array, MATLAB/Simulink.**

1. INTRODUCTION

Global warming and energy policies have become a hot topic on the international agenda in the last years. Developed countries are trying to reduce their greenhouse gas emissions. For example, the EU has committed to reduce the emissions of greenhouse gas to at least 20% below 1990 levels and to produce no less than 20% of its energy consumption from renewable sources by 2020 [1]. In this context, photovoltaic (PV) power generation has an important role to play due to the fact that it is a green source. The only emissions associated with PV power generation are those from the production of its components. After their installation they generate electricity from the solar irradiation without emitting greenhouse gases. In their lifetime, which is around 25 years, PV panels produce more energy than that for their manufacturing [2]. Governments are promoting it with subsidies or feed-in tariffs, expecting the development of the technology so that in the near future it will become competitive [3]-[4]. Increasing the efficiency in PV plants so the power generated increases is a key aspect, as it will increase the incomes, reducing consequently the cost of the power generated so it will approach the cost of the power produced from other sources. The efficiency of a PV plant is affected mainly by factors such as: the efficiency of the PV panel (in commercial PV panels it is between 8-15% [3]), the efficiency of the inverter (95-98 % [5]), the efficiency of the maximum power point tracking (MPPT) algorithm (which is over 98% [6]) and open and short-circuited PV modules in a string.

1.1 Proposed Method

A fault detection algorithm acting on the power conditioning system of the PV plant using wavelet transform is proposed in [7]. This method detects the fault and its location without any additional hardware. But this method has high cost and re-design problem if the inverter specification has been changed. An automatic fault detection method based on the power losses analysis is proposed in [8]. This method detects faults that occur only on the DC side of the PV system. The method can identify four different types of faults: faulty modules in a string, faulty string, false alarm and combined faults such as partial shadow, ageing, and MPPT error. In this paper, the classification and detection of all possible faults in both AC and DC side GCPV system using fuzzy logic are presented, where 100 kW array connected to a 25-kV grid via a DC-DC boost converter and a three-phase three-level VSC.

2. FUZZY LOGIC CONTROLLER (FLC)

Fuzzy logic is a very powerful method of reasoning when mathematical formulations are infeasible and input data are imprecise[9]-[11]. In this case fuzzy logic is a powerful tool for designing the control system accurately. Fuzzy logic application mainly to control is being studied throughout the world by control engineers. The result of these studies has shown that fuzzy logic is indeed a powerful control tool, when it comes to control system or process. Some studies have also shown that fuzzy logic performs better when compared to conventional control PI. There are specific components characteristic of a fuzzy controller to support a design procedure. In the block diagram shown in Fig.1, the controller is between a pre-processing block and a post-processing block.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 03 | Mar 2019 www.irjet.net p-ISSN: 2395-0072

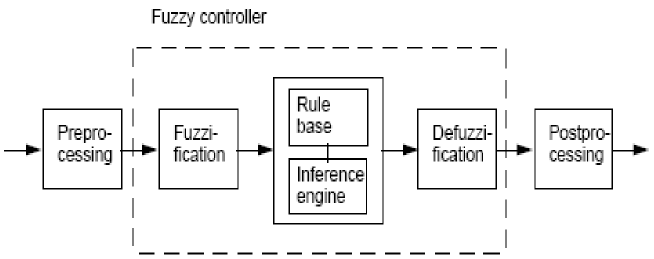

Fig-1: Block diagram of fuzzy logic controller

2.1 Pre-Processing

The inputs are most often hard or crisps measurements from some measuring equipment, rather than linguistic. A pre-processor, conditions the measurements before they enter the controller. Examples of pre-processing are

a) Quantisation in connection with sampling or rounding to integers;

b) Normalisation or scaling onto a particular, standard range;

c) Filtering in order to remove noise;

d) Averaging to obtain long term or short-term tendencies.

A quantizer is necessary to convert the incoming values in order to find the best level in a discrete universe.

2.2 Fuzzification

The first block inside the controller is fuzzification, which converts each piece of input data to degrees of membership by a lookup in one or several membership functions. The fuzzification block thus matches the input data with the conditions of the rules to determine how well the condition of each rule matches input instance. There is a degree of membership for each linguistic term that applies to that input variable.

2.3 Rule Base

Fuzzy sets and fuzzy operators are the subjects and verbs of fuzzy logic. These if-then rule statements are used to formulate the conditional statements that comprise fuzzy logic. A single fuzzy if-then rule assumes the form

if x is A then y is B

Where A and B are linguistic values defined by fuzzy sets on the ranges (universes of discourse) X and Y, respectively. The if-part of the rule "x is A" is called the antecedent or premise, while the then-part of the rule "y is B" is called the consequent or conclusion.

2.4 Membership Function

There are different memberships functions associated with each input and output response. Some features to note are: Shape, Height, Width, Centre, Overlap. In fuzzy control applications, Gaussian or bell-shaped functions and S-functions are not normally used. Functions such as Γ-function, L-function and Λ-function are far more common.

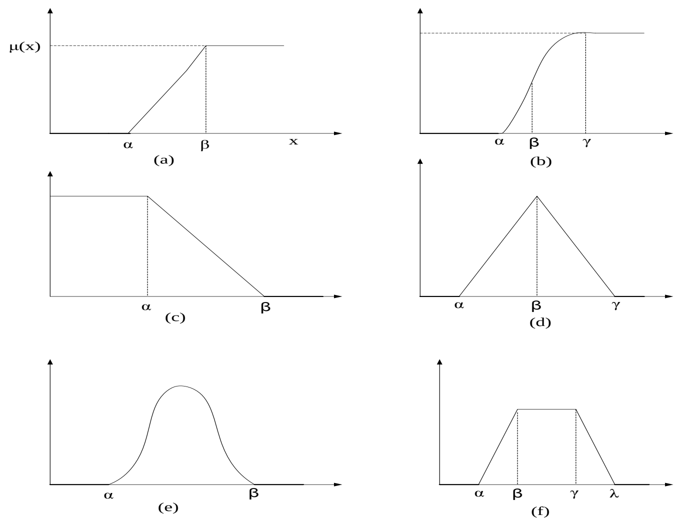

Fig-2: Types of membership functions: (a) Γ- function; (b) S-function; (c) L-function;(d) Λ-function;(e) Gaussian function; (f) Π-function.

2.5 Interference Engine

There are two type of approaches employed in the design of the inference engine of a FLC.

- Composition based inference.
- Individual rule-based inference.

In composition-based inference, the fuzzy max-min composition operator is employed. The rule base matrix represents the fuzzy relation matrix, R. R is then composed with e first and then the resulting fuzzy relation is composed with δe.

The basic function of second type inference is to compute the overall value of the control output variable based on individual contribution of each rule in the rule base. Each such individual contribution represents the value of control output variable as computed by single rule. The output of the fuzzification module, representing the current crisp value of the process state variables, is matched to each rule antecedent and a degree of match for each rule is established. Based on this degree of match, the value of control output variable in the rule antecedent is modified. i.e., the clipped fuzzy set representing fuzzy value of the control output variable is determined. The set of all clipped fuzzy sets represents the overall fuzzy output.

2.5 Defuzzification

The function of defuzzification module (DM) is as follows.

- Performs the so called defuzzification which converts the set of modified control output values into a single point-wise value.
- Performs an output demoralization which maps the point-wise value of the control output into on its physical domain. This step is not needed if non-normalized fuzzy sets are used.

3. SYSTEM MODELLING

Mainly the faults are identified as AC faults such as inverter side fault and DC fault which are listed as below

Faults AC side:

1. Total Blackout
2. Grid outage
3. Inverter

Faults at DC side:

1. PV array
2. MPPT

In system modelling, the boost converter is designed and the resistive load is connected. Then it is connected to inverter and tested. After that the boost converter control is changed to MPPT and the inverter control is changed to DQ control. Then the system is connected to grid and tested. Here the faults are analysed for the following conditions under different cases.

i) PV system fault

ii) Grid side fault

iii) DC-link faultR.

Case 1: Boost converter with resistive load

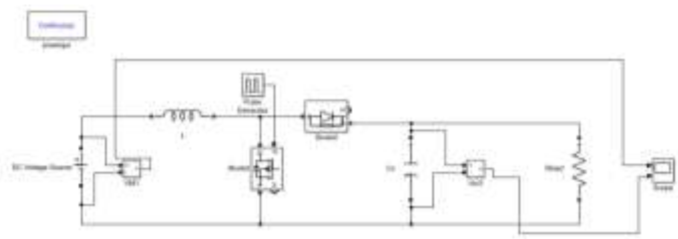

Fig-3: Boost Converter Simulation model.

The above figure shows the Simulink model of boost converter. A boost converter (step-up converter) is a power converter with an output DC voltage greater than its input DC voltage. It is a class of switching mode power supply (SMPS) containing at least two semi-conductors switches (a diode and a transistor) and at least one energy storage element. Filters are normally added to the output of the converter to reduce output voltage ripple. A boost converter is sometimes called a step-up converter since it “steps up” the source voltage. Since power (P = VI) must be conserved, the output current is lower than the source current.

Case 2: boost converter with inverter connected to three phase R load

In the proposed system three-phase three-level Voltage Source Inverter is used. Switch-mode dc-to-ac inverters used in ac power supplies and ac motor drives where the objective is to produce a sinusoidal ac output whose magnitude and frequency can both be controlled. Practically, we use an inverter in both single-phase and three phase ac systems.

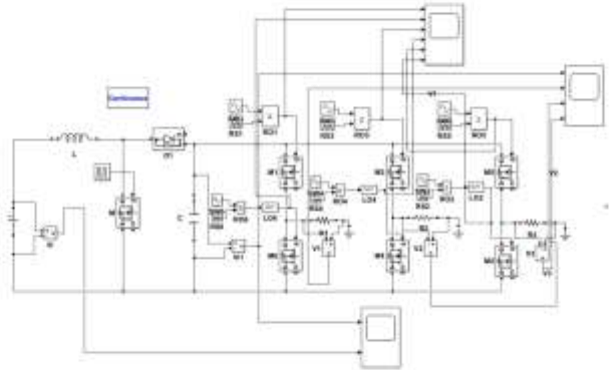

Fig-4: Combined boost and Inverter.

Case 3: Boost, MPPT, inverter and grid connected without fault

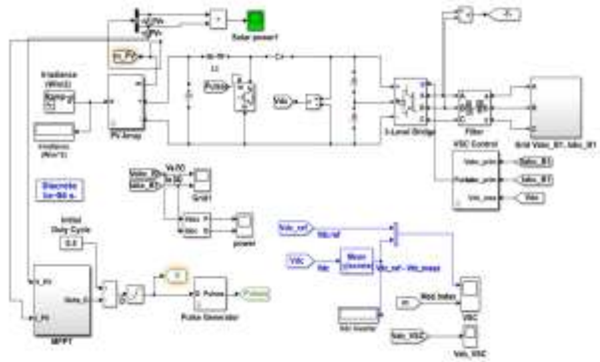

Fig-5: Complete simulation of boost, MPPT, inverter connected to grid

In the above Simulink model boost, inverter and MPPT [12] are connected to the grid and case study is done to know the output of the system under no fault condition. Performance of the system can be increase by using MPPT. Maximum Power Point Tracking is a technique used in photovoltaic cell to extract the maximum power under all environmental conditions[13]-[17].

Case 4: Boost, MPPT, inverter and grid connected with PV side fault

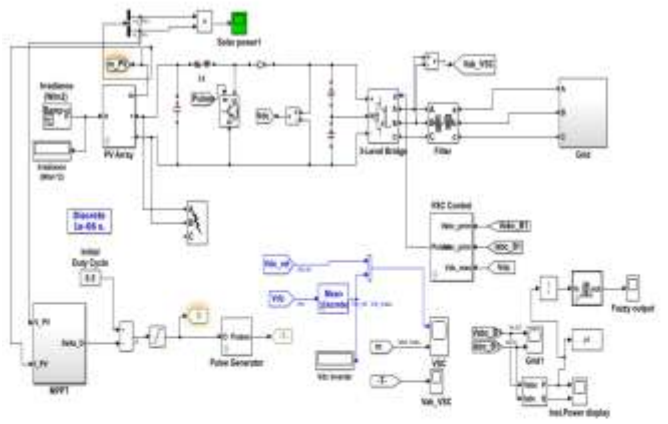

Fig-6: Simulation of boost, MPPT, inverter and grid with PV fault

In this case a fault is created at PV side to analyze the performance of the system at 1.5 sec to 2 sec by creating short circuit at PV side. When short circuit occurs fuzzy identifies the change in active and reactive power.

Case 5: Boost, MPPT, inverter and grid connected with Grid side fault

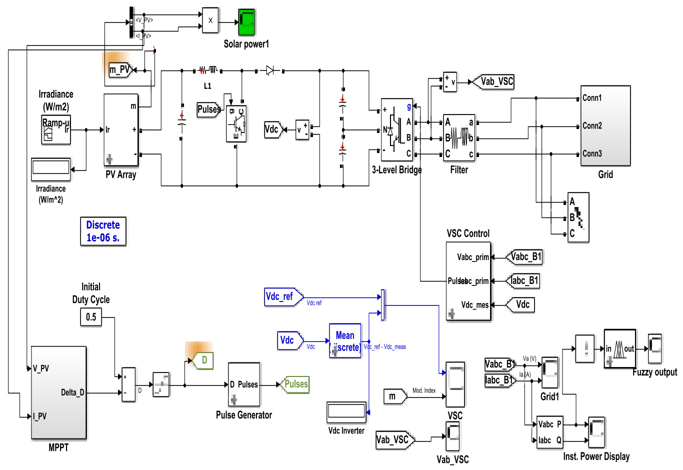

Fig-7: Simulation of boost, MPPT, inverter and grid with grid fault

Above figure shows the Simulation of boost, MPPT, inverter and grid with grid fault. Fault is created at grid side at 1.5 sec to 2 sec. Performance of the grid at this condition can be analyzed with the help of simulation output patterns.

Case 6: Boost, MPPT, inverter and grid connected with DC-link side fault

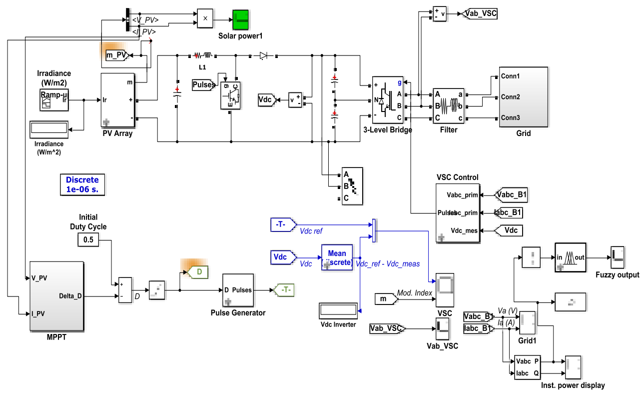

Fig-8: Complete simulation of boost, MPPT, inverter connected to grid with DC-link fault.

Figure 8 shows the complete simulation of boost, MPPT, inverter connected to grid with DC-link fault, which is created at 1.5sec. pattern of outputs obtained through simulation is different for each case.

4. Simulation Results.

4.1 Boost converter input and output voltages

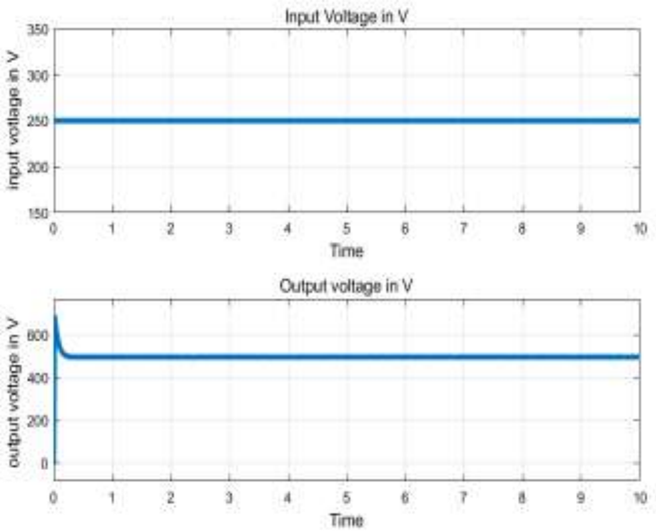

Fig-9: Input Voltage and Output voltage of boost converter.

Above figure represents the simulation outputs for case 1. Boost converter gives the DC output for the input of 250V DC. The resistance used at the output of the boost converter is of 10 ohms.

4.2 Combination of Boost Converter, Inverter and 3 phase R load.

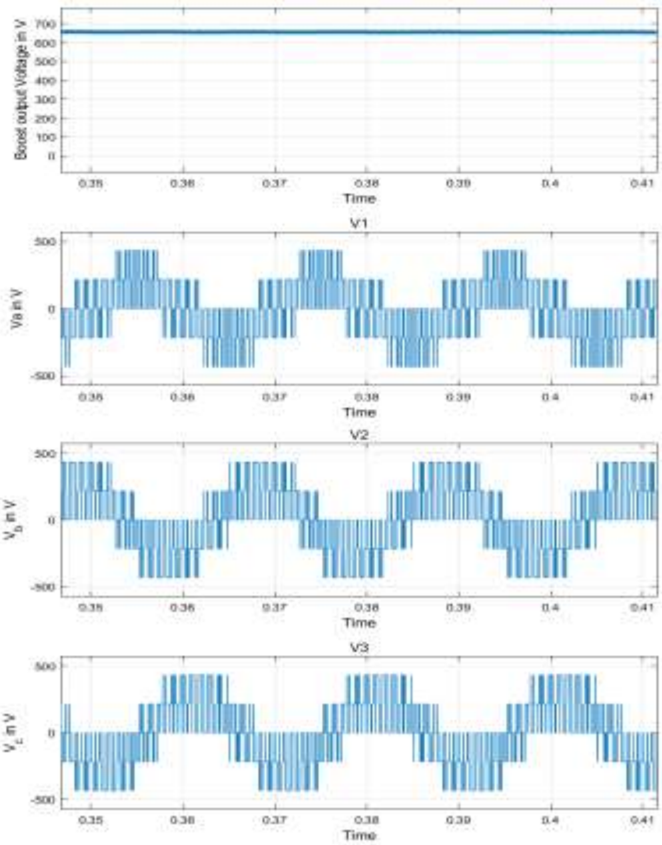

Fig-10: Output voltages across Boost converter and Inverter.

The input voltage is boosted and the boosted voltage is inverted and given to AC R-load.

4.3 No Fault.

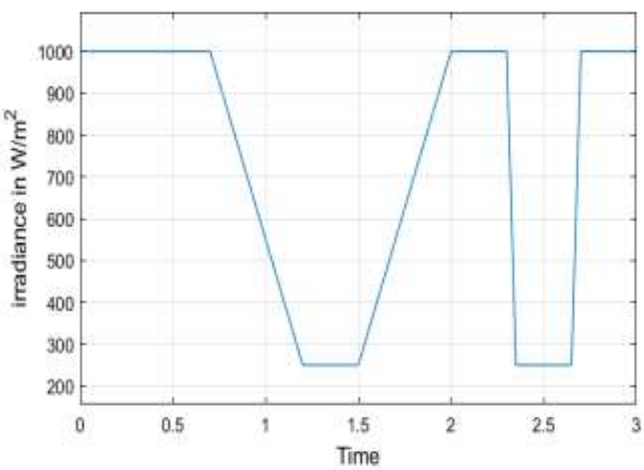

Fig-11: Solar Irradiance.

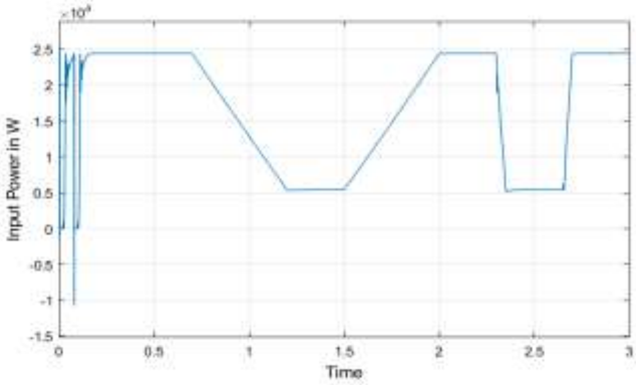

Fig-12: Solar Input power.

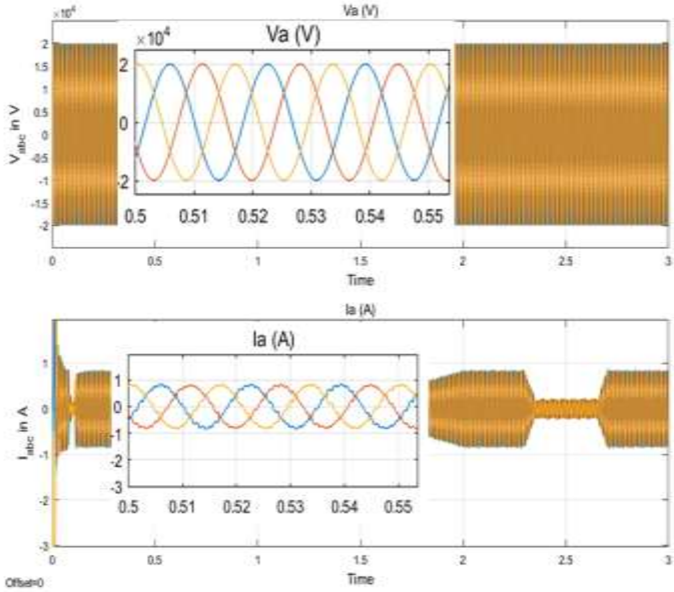

Fig-13: Grid Voltage and current.

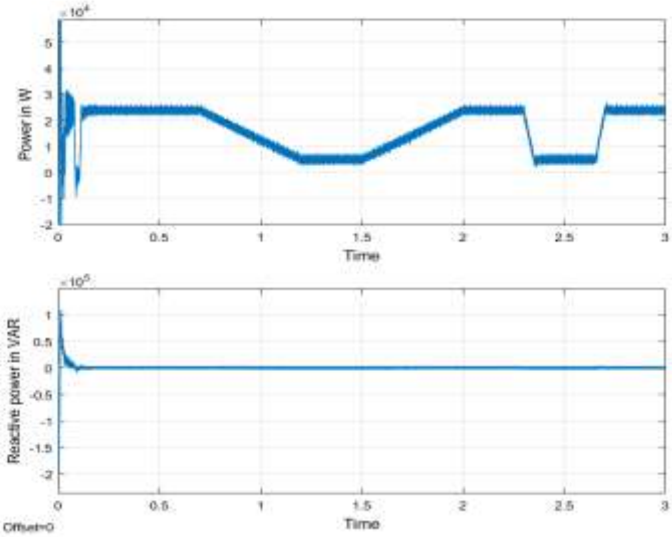

Fig-14: Grid Real and Reactive power.

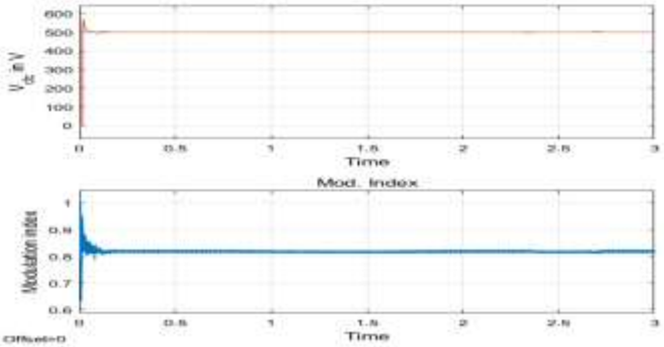

Fig-15: DC link voltage and Modulation Index

The above simulations results are for No Fault condition. Here Boost, MPPT, inverter are connected to the grid. For Irradiance of 1000 W/msq solar input Power is 2.5W as shown in Fig-12. Under no fault condition reactive power of the grid is zero and there are traces of real power as shown in Fig-14 The modulation index obtained without fault is 0.8 shown in Fig-15.

4.4 PV side Fault.

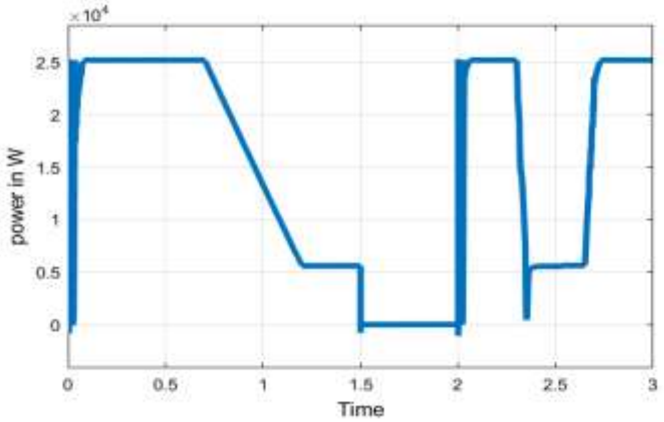

Fig-16: PV side Power with short circuit (faulted at 1.5 to 2 secs)

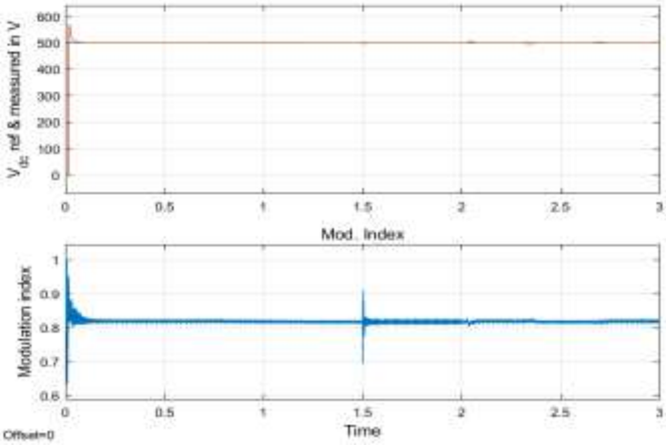

Fig-17: Vdc link voltage and modulation index with short circuit (PV side faulted at 1.5 sec to 2 secs)

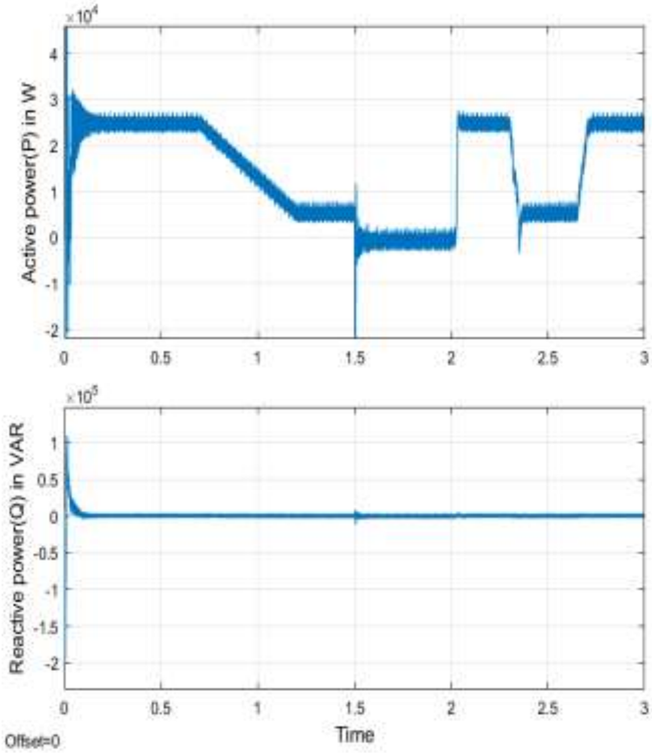

Fig-18: Active power reactive power with short circuit (PV side faulted at 1.5 sec to 2 secs)

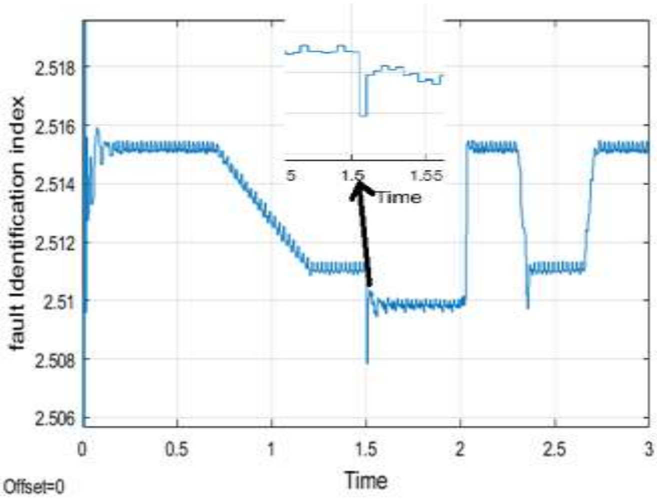

Fig-19: Fault identification index by fuzzy (PV side faulted at 1.5 sec to 2 secs)

At PV side of the system a short circuit is created at 1.5 sec to 2 sec to study the performance of the system. Under no fault condition at 1.5sec there are no disturbances in the parameters of the system such as modulation index , active power and reactive power but, as soon as short circuit occurs we can see that the performance of the system is affected and during this condition FLC identifies disturbance in terms of Fault identification index as shown in Fig-19.

4.5 Grid side Fault

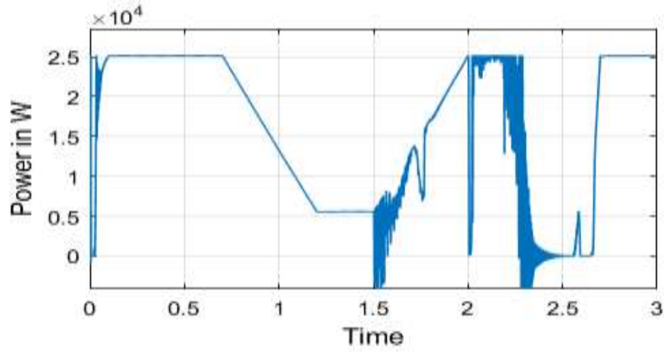

Fig-20: PV side power with short circuit (grid faulted at 1.5 sec to 2 secs)

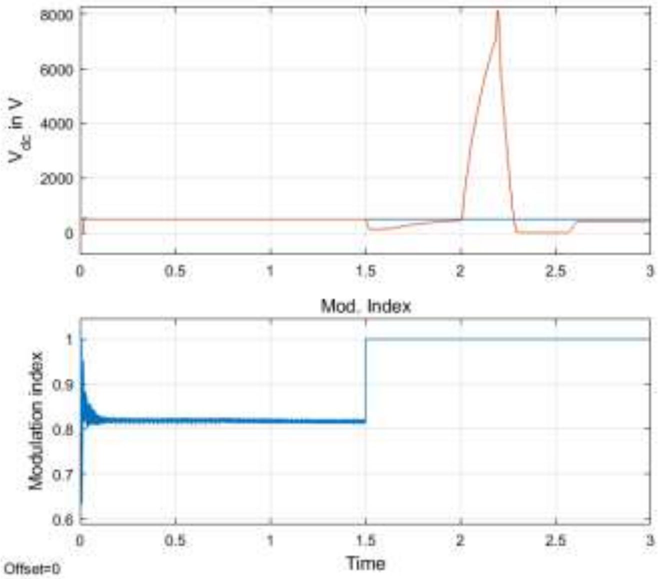

Fig-21: Vdc link voltage and modulation index with short circuit (grid side faulted at 1.5 sec to 2 secs)

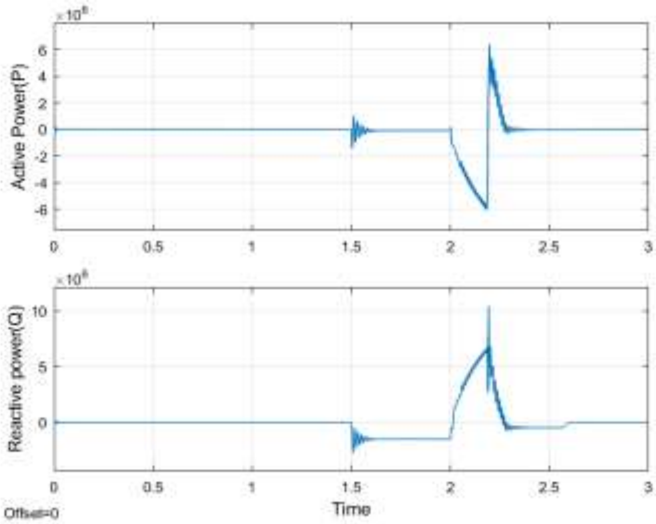

Fig-22: Active power reactive power with short circuit (Grid side faulted at 1.5 sec to 2 secs)

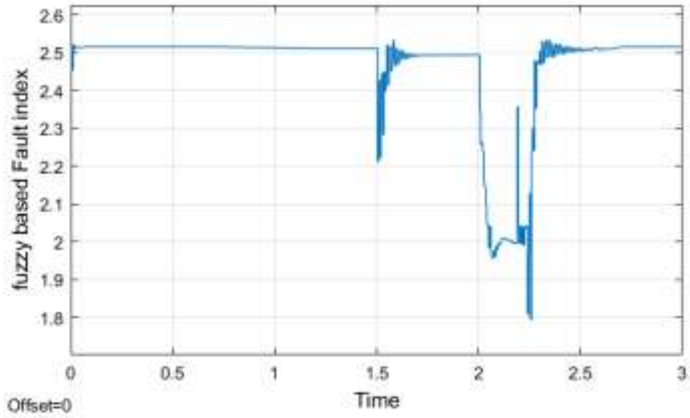

Fig-23: Fault identification index by fuzzy (grid side faulted at 1.5 sec to 2 secs)

In this case a short circuit is created at 1.5sec to 2secs at Grid side. During this condition it can be seen a new pattern of link voltage, modulation index, active power, reactive power and fault index are displayed, which shows the detection of grid faults by FLC.

4.6 DC link side Fault.

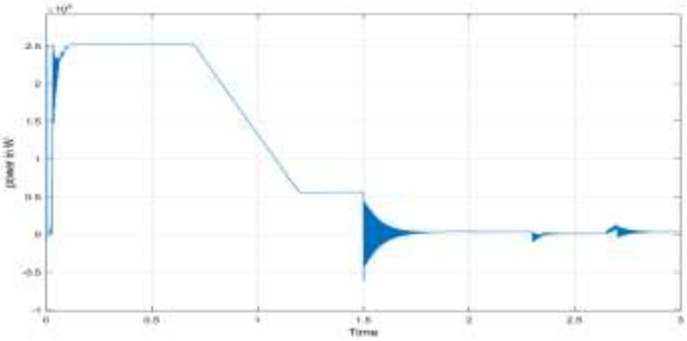

Fig-24: Solar input power (DC-link faulted at 1.5 secs)

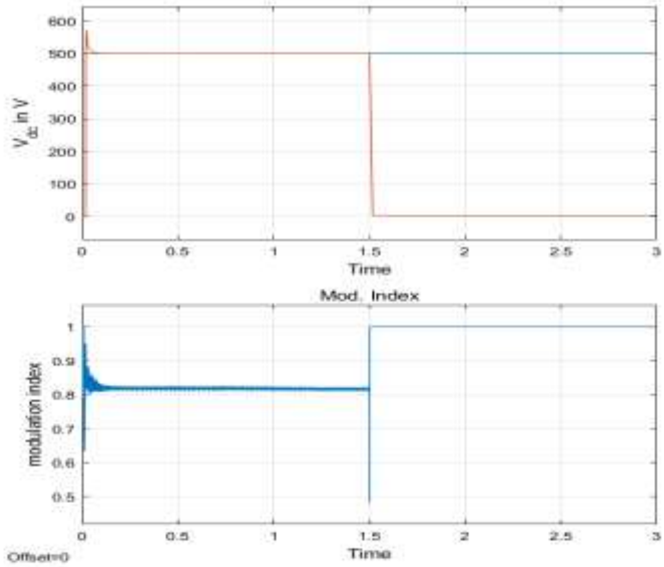

Fig-25: DC-link Voltage and modulation index

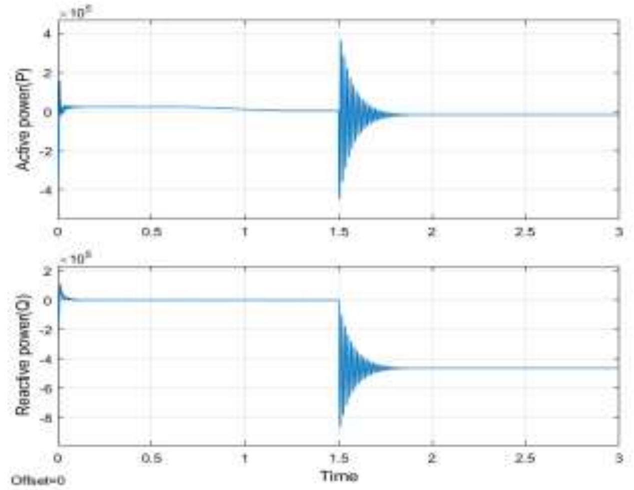

Fig-26: Grid real and reactive power (DC-link faulted at 1.5 secs)

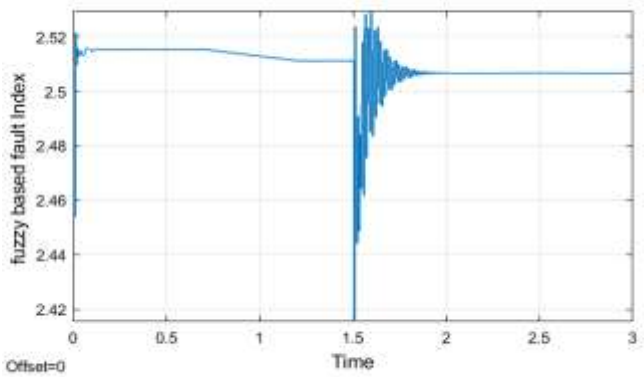

Fig-27: Fault index using fuzzy (DC-link faulted at 1.5 secs)

During the fault at DC link side patterns of waveforms identified by FLC for Solar power, modulation index, active power, reactive power and fault index are completely different from the previous case 4.4 & 4.5.

4.7 GCPV system details.

Table-1: GCPV system details

Description	Values	Description	Values
Boost Converter	272V DC to 500V DC	Frequency	5KHZ
VSC	500V DC	Frequency	1980 HZ (30*60)
Grid	100kVA,250V/25KV	Transmission system	120kV equivalent
PV array	100kW	Specification	SPR-305, 66 strings of 5 series connected

CONCLUSION

This paper presents the fault classification using fuzzy in a distributed generation, particularly photovoltaic 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 using fuzzy logic controller (FLC). Mainly the faults are identified as AC faults such as inverter side fault and DC fault such as fault in PV array and Dc link fault. A case study of a 100 kW array connected to a 25 kV grid via a DC-DC boost converter and a three-phase three-level Voltage Source Converter (VSC) system used to illustrate the proposed FLC control through MATLAB/Simulink software.

REFERENCES

[1] The European Union climate and energy package, (The “20 – 20 – 20” package).[Accessed 28/10/2010].

[2] D. JC. MacKay, “Sustainable Energy - Without the Hot Air”, UIT Cambridge, 2009.[Accessed 28/10/2010].

[3] “Trends in photovoltaic applications. Survey report of selected IEA countries between 1992 and 2009”, International Energy Agency, Report IEA-PVPS Task 1 T1-19:2010. Photovoltaic_2010.pdf [Accessed 28/10/2010].

[4] P. A. Lynn, Electricity from Sunlight: An Introduction to Photovoltaics, John Wiley & Sons, 2010, p. 238.

[5] “Sunny Family 2010/2011 - The Future of Solar Technology”, SMA product catalogue, 2010.[Accessed 14/12/2010].

[6] L. Piegari, R. Rizzo, "Adaptive perturb and observe algorithm for photovoltaic maximum power point tracking," Renewable Power Generation, IET, vol. 4, no. 4, pp. 317-328, July 2010.

[7]Zhao Y, Yang L, Lehman B, DePalma JF, Mosesian J and Lyons R, “Decision-based fault detection and classification in solar photovoltaic arrays,” in proceedings of the Twenty seventh annual IEEE applied power electronics conference and exposition, pp.93-99, 2012.

[8] Il-Song K, “Fault detection algorithm of the photovoltaic system using wavelet transform,” in proceedings of the IEEE India international conference on power electronics, New Delhi, pp.1-6, 2010.

[9 Jan Jantzeni. “Foundations of Fuzzy Control”, John Wiley & Sons, 2007

[10] Kapil Dev Sharma and Mohammad Ayyub, "Fuzzy Logic Controller (FLC) with Better Performance as Against Conventional PID Controller" Presented in 2nd National Conference on "Recent Advances in Technology and Engineering (RATE-2013)", March 15-17, 2013, held at Mangalayatan University, Aligarh, India.

[11] Arpit Goel, Ankit Uniyal, Anurag Bahuguna, Rituraj S. Patwal And Husain Ahmed, "Performance comparison of PID and fuzzy logic controller using different defuzzification techniques for positioning control of dc motors", Journal of Information Systems and Communication Vol.3, Issue 1, pp. 235-238, 2012.

[12] N. Femia, G. Petrone, G. Spagnuolo, M. Vitelli, "Optimizing sampling rate of P&O MPPT technique," in Proc. IEEE PESC, 2004, pp. 1945- 1949.

[13] G. M. S. Azevedo, M. C. Cavalcanti, K. C. Oliveira, F. A. S. Neves, Z. D. Lins,"Evaluation of maximum power point tracking methods for grid connected photovoltaic systems," in Proc. IEEE PESC, 2008, pp. 1456-1462.

[14] Overall efficiency of grid connected photovoltaic inverters, European Standard EN 50530,
2010.

[15] D. Sera, T. Kerekes, R. Teodorescu, F. Blaabjerg, "Improved MPPT Algorithms for Rapidly Changing Environmental Conditions," in Proc. 12th International Conference on Power Electronics and Motion Control, 2006, pp. 1614-1619.

[16] D. Sera, T. Kerekes, R. Teodorescu, F. Blaabjerg, "Improved MPPT method for rapidly changing environmental conditions," in Proc. IEEE International Symposium on Industrial Electronics, 2006, vol. 2, pp. 1420-1425.

[17] N. Femia, G. Petrone, G. Spagnuolo, M. Vitelli, "Optimization of perturb and observe maximum power point tracking method," IEEE Transactions on Power Electronics, vol. 20, no. 4, pp. 963-973, July 2005.