Design and Fault analysis of Photovoltaic Cable Array with Grid Connected Systems

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Abstract : The environmentally clean nature of solar photovoltaic (PV) technology causes PV power generation to be embraced by all countries across the globe. The photovoltaic system (PV) has attracted much attention due to the oil and environment pollution in recent years. In this paper, the cable fault characteristics of the PV powers are analyzed in detail and both the line-to-ground fault and the line-to-line fault are involved. The fault processes are divided into several sub modules. All the analysis is verified by the simulation model based on the MATLAB/SIMULINK and with the help of simulation results. Simulated results show that proposed model gives efficient fault analysis when using PV cable Array.

***IndexTerms* - PV, Fault, Line, Ground, Simulink, Array, Power, Grid.**

I. INTRODUCTION

Growing demand for electric power, the restriction of fossil energy sources, air pollution, and the greenhouse effect because of using fossil energy sources are among the reasons indicating the importance of renewable energy sources such as solar and wind power. Cost-effective, reliable, and efficient PV inverters enable the successful utilization of this renewable energy resource. One of the major factors in PV inverters' failures is the usage of electrolytic capacitors. Some efforts have been made to reduce the size of capacitors needed in single-phase inverters and to replace the electrolytic capacitors with the non-electrolytic capacitors. In these methods, however, additional elements are employed and the switching patterns are complex.

When soft switching is employed in inverters, switching frequency can be increased. As a result, smaller filter elements are used. Thus, the inverter's power density increases. Moreover, soft switching increases the reliability of the inverter because it reduces the stress on the switches. To reach soft switching, several approaches have been proposed based on using ac link instead of dc link. A quasi-dc link converter is introduced. In this converter, soft switching is achieved by switching between states at the intervals where the link voltage is zero.

As the foundation of designing protection schemes, the fault analysis is essential and indispensable, but the existing researches almost all focused on the fault characteristics of voltage source converters (VSCs) and ignored other sources. Reference has analyzed the DC microgrids fault characteristics briefly and proposed that the fault current would include both the current from generators and the capacitances discharging current. Reference has divided the pole-to-pole fault process of VSCs into three stages and divided the pole-to ground fault process into two stages. Then, each stage has been analyzed in detail. Reference have further improved analysis result in the second stage of a pole-to-pole fault which is most dangerous for the equipment safety has been emphasized and references have proposed that this stage can be avoid when the fault circuit is underdamped and employing the superconductive fault current limiter is an ideal solution.

However, many switches are used in this structure. Partial resonant converter has been introduced in which the resonance of a parallel LC tank and the ac link provides soft switching conditions at the intervals where the link voltage or current is zero. In the partial resonant converter with some modifications has been used in PV applications. This topology, however, suffers from the dependence of link frequency to the output power. In addition, the control method is not straightforward and the computational burden increases with increase in link frequency. As the voltage of renewable energy sources, such as PV and fuel cell, varies widely in their power range, the buck–boost topology has attracted a lot of attention recently. Moreover, in transformerless PV inverters, the common-mode current must be rejected. For single-phase applications, multiple topologies have been introduced. In addition, some three-phase inverters based on buck–boost topology have been proposed in the literature. For instance, a three-phase fly back inverter is introduced in with sinusoidal pulse width modulation switching pattern. The same topology has been employed in with space vector modulation (SVM) technique. The work in presents various control methods in current source inverters. For example, in the PV current is controlled to track the MPP, and a modified SVM is used to generate the gate signals. In the MPPT block determines the reference of a PV voltage and then the voltage of a PV panel is regulated to this reference value. In a sliding mode control based on SVM is employed and the PV power is controlled directly to realize the MPPT function.

II. BACKGROUND

Power processing systems will be a key factor of future photovoltaic (PV) applications. They will play a central role in transferring, to the load and/or to the grid, the electric power produced by the high-efficiency PV cells of the next generation. In order to come up the expectations related to the use of solar energy for producing electrical energy, such systems must ensure high efficiency, modularity, and, particularly, high reliability. The goal of this paper is to provide an overview of the open problems related to PV power processing systems and to focus the attention of researchers and industries on present and future challenges in this field.

In addition, the recent research and emerging PV converter technology are discussed, highlighting their possible advantages compared with the present technology. This phenomenon has been possible because of several factors all working together to push the PV energy to cope with one important position today (and potentially a fundamental position in the near future). Among these factors are the cost reduction and increase in efficiency of the PV modules, the search for alternative clean energy sources (not based on fossil fuels), increased environmental awareness, and favorable political regulations from local governments Grid-connected PV systems account for more than 99% of the PV installed capacity compared to stand-alone systems (which use batteries). In grid-connected PV systems, batteries are not needed since all of the power generated by the PV plant is uploaded to the grid for direct transmission, distribution, and consumption. Hence, the generated PV power reduces the use of other energy sources feeding the grid, such as hydro or fossil fuels, whose savings act as energy storage in the system, providing the same function of power regulation and backup as a battery would deliver in a stand-alone system. Since grid-connected systems do not need batteries, they are more cost-effective and require less maintenance and reinvestment than stand-alone systems. This concept together with the cost reduction, technology development, environmental awareness, and the right incentives and regulations has unleashed the power of the sun.

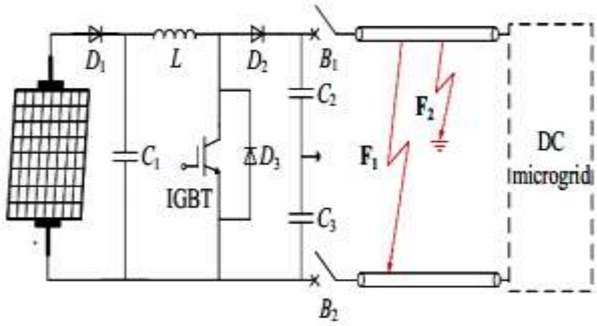


Figure 1: Previous model block diagram [1]

Where, the D1 is an isolating diode, which is used for preventing the current from reversing into the PV power. The DC-DC converter is consisted of the L, D2, D3 and an insulated gate bipolar transistor (IGBT).

It is essential for the proposed converter to perform bidirectional power flow control and fulfill utility interface measures, with just a single power-handling stage. The collapsed grid current input and output speaks to the power flow direction and the moved power level. It additionally remembers the power quality for the grid side. Along these lines, controlling the collapsed grid current input and output prompts the attainability of single-power conversion in the proposed converter.

The proposed converter is inferred by incorporating a full-bridge MOSFET diode rectifier and an arrangement thunderous dynamic cinch DC–DC converter. To acquire a powerful factor without a power factor correction circuit. The proposed converter gives single power-conversion by utilizing the novel control algorithm for both power factor correction and output control. Additionally, the dynamic clasp circuit braces the flood voltage of switches and reuses the energy stored in the spillage inductance of the transformer. Moreover, it gives zero voltage turn-on switching of the switches. Likewise, an arrangement thunderous circuit of the output-voltage doubler expels the turnaround recuperation issue of the output diodes.

III. PROPOSED MODEL

The main objective is to design and fault analysis of solar photovoltaic cable array grid connected systems. Previously it analysis for single PV cable, but in some application there is need to use PV cable array. Therefore proposed model have PV cable array and fault analysis perform with accuracy.

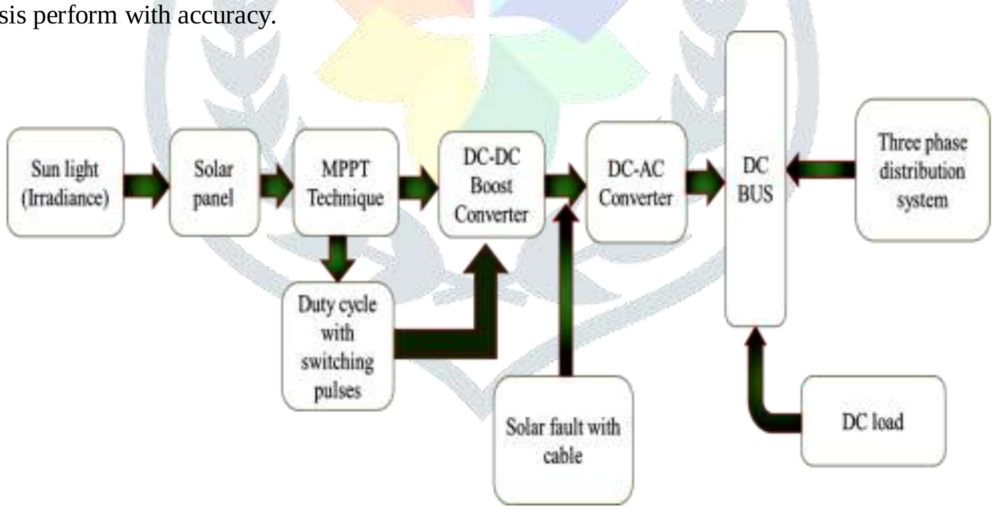


Figure 2: Proposed Flow Chart

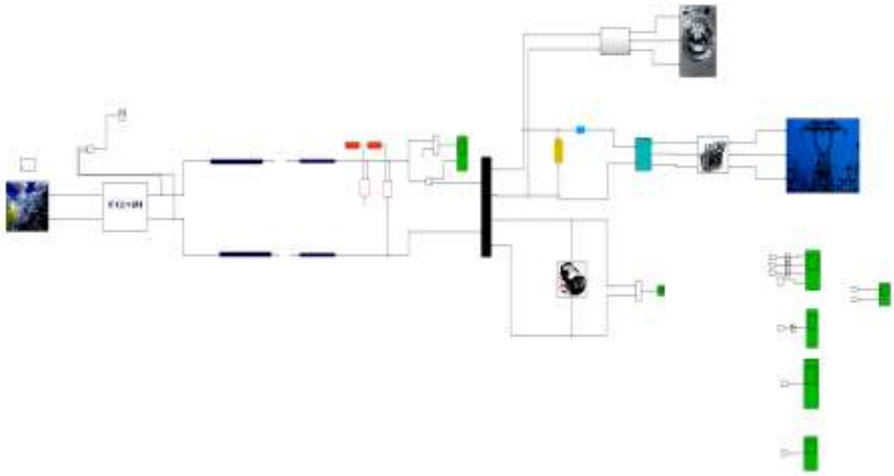


Figure 3: Proposed Model

Figure 3 shows proposed model of fault analysis of dc microgrid with PV cable. In this model, there are sub modules like three phase grid, DC-DC converter, pulse width modulation, Solar panel and MPPT.

Following sub module are used to design proposed model. Each module is connected as per flow block diagram.

- Three phase grid
- DC-DC converter and DC-AC converted
- pulse width modulation(PWM)
- Solar panel
- MPPT Technique

Standard Solar, Inc. as of late finished one of the principal solar microgrid systems with a gridinteractive battery bank in the nation. Being an originally was a test it took a very long time of devotion, inventive building and coordination with key accomplices, utilities and government workplaces to make this venture a reality. The primary portion of this paper will set the phase by clarifying how the microgrid is arrangement, its usefulness and what makes it uncommon. At that point I will investigate the stuff to plan and introduce a solar microgrid system, the exercises gained from this groundbreaking undertaking and what specialized contemplations ought to be made when actualizing this new innovation.

Maximum power point tracking (MPPT) is a calculation actualized in photovoltaic (PV) inverters to constantly modify the impedance seen by the solar cluster to keep the PV system working at, or near, the pinnacle power purpose of the PV panel under fluctuating conditions, such as changing solar irradiance, temperature, and burden. Architects creating solar inverters execute MPPT calculations to expand the power produced by PV systems. The calculations control the voltage to guarantee that the system works at "greatest power point" (or pinnacle voltage) on the power voltage bend, as demonstrated as follows. MPPT calculations are commonly utilized in the controller plans for PV systems. The calculations account for factors, for example, factor irradiance (daylight) and temperature to guarantee that the PV system produces most extreme power consistently. Most extreme power point tracking is a technique utilized normally with wind turbines and photovoltaic (PV) solar systems to boost power extraction under all conditions.

An electrical grid is an interconnected system for conveying power from makers to buyers. It comprises of creating stations that produce electrical power, high voltage transmission lines that convey power from far off sources to demand focuses, and circulation lines that interface singular clients. An AC-AC converter with around sinusoidal info currents and bidirectional power flow can be acknowledged by coupling a heartbeat width modulation (PWM) rectifier and a PWM inverter to the DC-interface.

IV. Simulation Results

The simulation studies involve the fault analysis model as shown in Figure 3. The proposed model is implemented with MATLAB simulink.

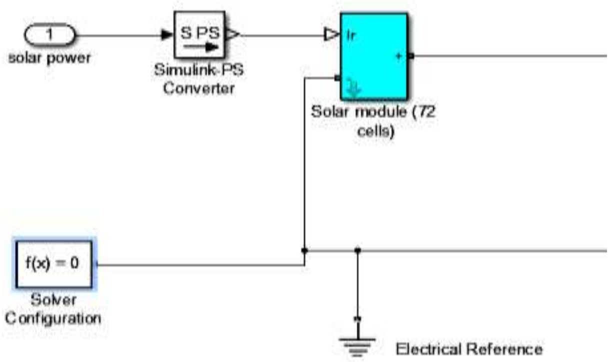
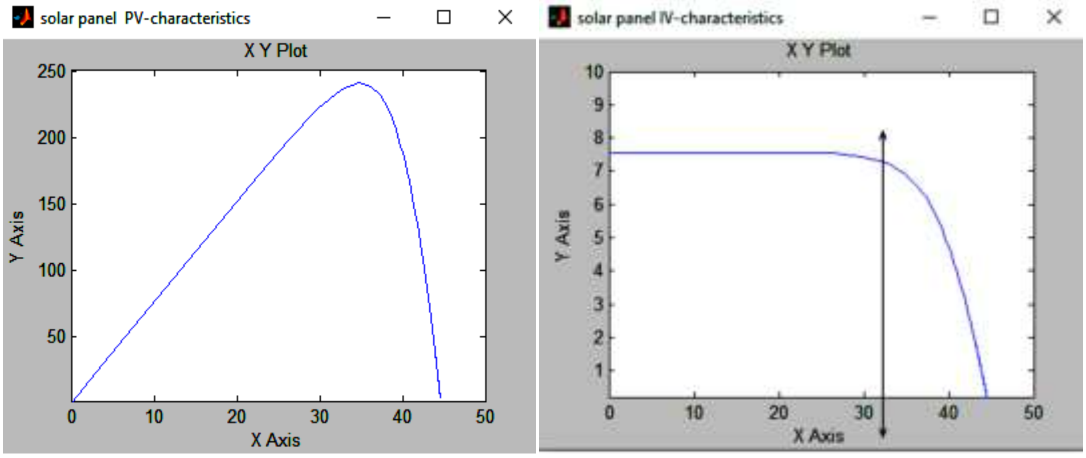


Figure 4: Solar panel

Figure 4 shows solar arrays, it begin with a single solar energy cell known as a photovoltaic cell. “Photo” essentially means light, and “voltaic” refers to voltage, which is a unit of potential electrical energy.



(a) (b)

Figure 5: (a) Voltage vs Power graph (b) Voltage vs Current graph

Figure 5(a) shows voltage vs power graph of solar panel PV- characteristics. X axis show the MPPT value of voltage i.e approx 32 while y axis shows the power i.e. 240W approx. Figure 5 (b) presents voltage vs current graph of solar panel PV-characteristics. X axis show the value of voltage i.e approx 32 while y axis shows the power i.e. 7.5A approx.

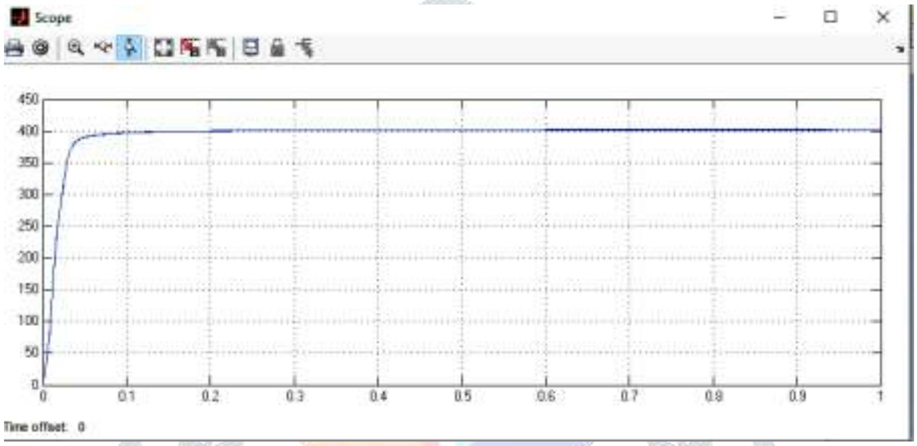


Figure 6: Voltage of DC-DC Converter

Figure 6 is showing voltage of DC-DC converter, it achieves 402.8 voltages. In previous model IGBT is used but in proposed model MOSFET is used instead of IGBT.

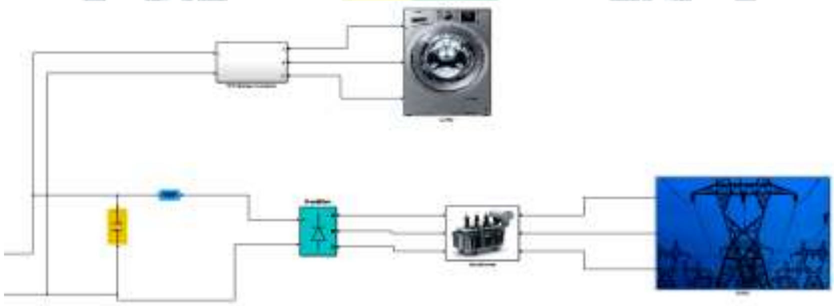


Figure 7: Load and AC Grid

Figure 7 presents the load element and AC grid. Here 2 phase power line is converted into 3 phase power line by using bridge converter and rectifier.

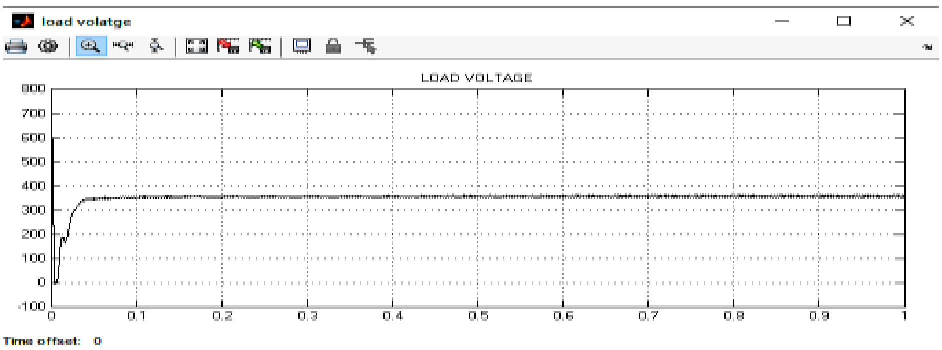


Figure 8: Load Voltage

Figure 8 is showing output of load. Here 380V is achieved at the output side in this model. So this voltage can be used for any industrial or domestic application.

1. Line-to-Line fault

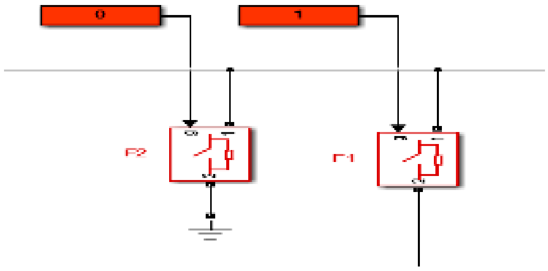


Figure 9: Line-to-Line fault

Figure 9 is showing line-to-line fault condition. In which line have fault while ground have no fault. A line to line fault is one where short circuiting occurs between two phases of a system.

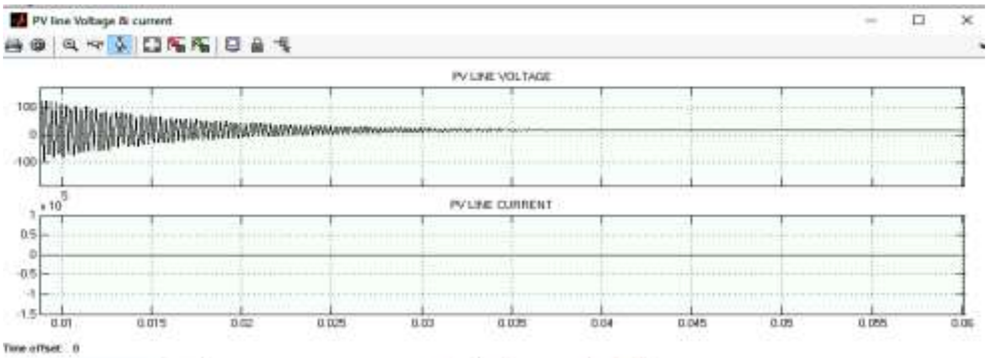


Figure 10: PV line voltage and current graph-2

Figure 10 is showing line-to-line fault voltage and current. The value of voltage is 12V and current is 0A

2. Line to ground fault

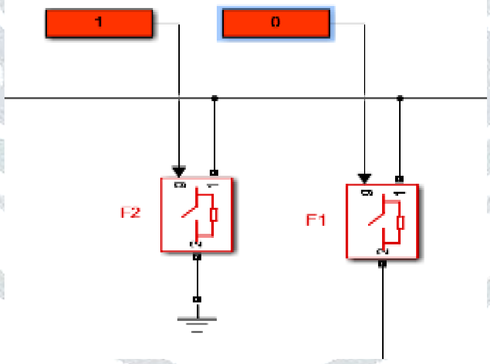


Figure 11: Line to ground fault

Figure 11 is showing line-to-ground Fault. Generally, a single line-to-ground fault on a transmission line occurs when one conductor drops to the ground in which line have fault while ground have no fault.

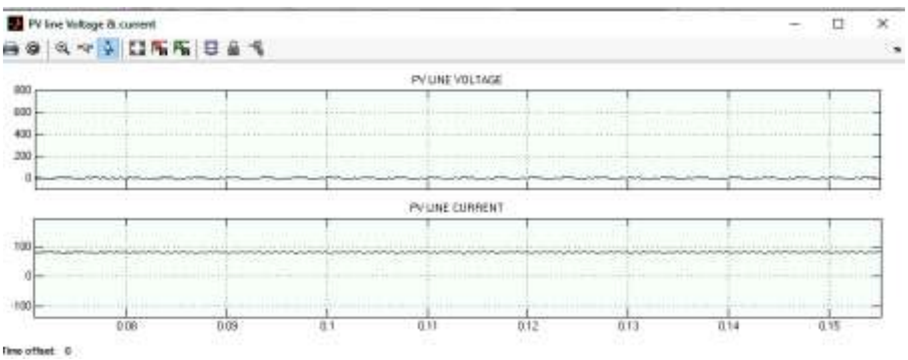


Figure 12: PV line voltage and current-3

Figure 12 is showing line-to-ground fault voltage and current. The value of voltage is 0V and current is 80A.

Table 1: Simulation Result

Sr No.	Fault condition	Voltage (V)	Current (A)
1	No fault	202	80
2	Line to Line	12	0
3	Line to Ground	0	80
4	Combined Fault	0	0

Table 2: Comparison of Previous Model with Proposed Model

Sr No.	Parameter	Previous Model	Proposed Model
1	Switch	IGBT	MOSFET
2	Output	DC Microgrid	DC & AC Microgrid
3	Fault	All case	All case
4	Load output voltage	Not Mention	380V
5	DC-DC converter Output Voltage	380 V	402.8 V
6	Software	PSCAD/EMTDC	MATLAB

Table 1 shows simulation results and table 2 showing comparison of proposed model analysis results with previous model results. Therefore above result shows, proposed model give significant improved analysis rather than the existing model.

V. CONCLUSION

The simulation results showed that the proposed research work involved fault analysis of proposed model design. More number of PV cable or array of cable indicate that used in large area application. Proposed model shows the utility of generated PV power in industries and home application. Therefore it is clear that proposed model and analysis is significant better than existing model.

REFERENCES

[1]. E. Mohanty, R. Swain, S. S. Pany, S. Sahoo, S. S. Behera and B. K. Panigrahi, "Detection of Symmetrical and Unsymmetrical Fault in a PV Connected Power System," *2019 3rd International Conference on Computing Methodologies and Communication (ICCMC)*, Erode, India, 2019, pp. 251-254.

[2]. G. Kou, L. Chen, P. VanSant, F. Velez-Cedeno and Y. Liu, "Fault Characteristics of Distributed Solar Generation," in *IEEE Transactions on Power Delivery*.

[3]. M. Akmal, F. Al-Naemi, N. Iqbal, A. Al-Tarabsheh and L. Meegahapola, "Impact of Distributed PV Generation on Relay Coordination and Power Quality," *2019 IEEE Milan PowerTech*, Milan, Italy, 2019, pp. 1-6.

[4]. P. Jain, J. Poon, J. P. Singh, C. Spanos, S. Sanders and S. K. Panda, "A Digital Twin Approach for Fault Diagnosis in Distributed Photovoltaic System," in *IEEE Transactions on Power Electronics*.

[5]. G. Suriya Priya and M. Geethanjali, "Design and Development of Distance Protection Scheme for Wind Power Distributed Generation," *2018 National Power Engineering Conference (NPEC)*, Madurai, 2018, pp. 1-6

[6]. D. Millare, R. Hadidi, M. H. McKinney, J. Leonard and J. C. Fox, "Calculations for Asymmetrical Fault Synthesis for Evaluating Ride-Through of Grid Connected Solar Inverters," *2018 9th IEEE International Symposium on Power Electronics for Distributed Generation Systems (PEDG)*, Charlotte, NC, 2018, pp. 1-5..

[7]. J. Crepaldi, M. M. Amoroso and O. H. Ando Junior, "Analysis of the Topologies of Power Filters Applied in Distributed Generation Units - Review," in *IEEE Latin America Transactions*, vol. 16, no. 7, pp. 1892-1897, July 2018.

[8]. A. Mishra, N. -. C. Nair and N. D. Patel, "Fault current characterisation of single phase inverter systems," *2017 IEEE Power & Energy Society General Meeting*, Chicago, IL, 2017, pp. 1-5.

[9]. S. P. George and S. Ashok, "Multiagent based adaptive relaying for distribution network with distributed generation," *2015 International Conference on Energy, Power and Environment: Towards Sustainable Growth (ICEPE)*, Shillong, 2015, pp. 1-6.

[10]. T. Yamamoto, X. Yanbin, S. Hashimoto, N. Higuchi, K. Nara and H. Yasue, "Operational simulation of PV generation system with hybrid batteries," *2015 IEEE Innovative Smart Grid Technologies - Asia (ISGT ASIA)*, Bangkok, 2015, pp. 1-5.

[11]. Y. Liu, P. Lan and H. Lin, "Grid-connected PV inverter test system for solar photovoltaic power system certification," *2014 IEEE PES General Meeting | Conference & Exposition*, National Harbor, MD, 2014, pp. 1-5.

[12]. F. Erhard, B. Schaller and F. Berger, "Field test results of serial DC arc fault investigationson real photovoltaic systems," *2014 49th International Universities Power Engineering Conference (UPEC)*, Cluj-Napoca, 2014, pp. 1-6.

[13]. S. P. George, S. Ashok and M. N. Bandyopadhyay, "Impact of distributed generation on protective relays," *2013 International Conference on Renewable Energy and Sustainable Energy (ICRESE)*, Coimbatore, 2013, pp. 157-161.

[14]. S. P. Pokharel, S. M. Brahma and S. J. Ranade, "Modeling and simulation of three phase inverter for fault study of microgrids," *2012 North American Power Symposium (NAPS)*, Champaign, IL, 2012, pp. 1-6.

[15]. S. Thale and V. Agarwal, "Controller Area Network (CAN) based smart protection scheme for Solar PV, fuel cell, Ultra-Capacitor and wind energy system based microgrid," *2012 38th IEEE Photovoltaic Specialists Conference*, Austin, TX, 2012, pp. 000580-000585.

[16]. Y. Song, W. Huang and X. Zhu, "A vision-based fault diagnosis system for heliostats in a central receiver solar power plant," *Proceedings of the 10th World Congress on Intelligent Control and Automation*, Beijing, 2012, pp. 3417-3421.