# Novel fault detection algorithms and evaluation of their deployment in multiple existing PV installations

**Ashutosh Kumar*[1], Dr. Sanjay Jain[2]**
*[1] M. Tech Student, Electrical Engineering Department, RKDF University, Bhopal, M.P.
kumar.ashu8@gmail.com[1]
[2] Professor & HOD, Electrical Engineering Department, RKDF University, Bhopal, M.P.
Jain.san12@gmail.com[2]

***ABSTRACT***

***The cumulative global photovoltaic (PV) capacity has been growing exponentially around the world, especially due to the installation of grid connected photovoltaic (GCPV) plants. Fault detection and analysis are important for the efficiency, reliability and safety of solar photovoltaic (PV) systems. Even This paper the results of the research work conducted to invent novel fault detection algorithms and evaluate their deployment in multiple existing PV installation, and empirically validate their performance. A major contribution of this thesis is the development of PV fault detection algorithms based on two indicators named power ratio (PR) and voltage ratio (VR). Both ratios are used to identify the type of the fault that occurs in the PV modules, in PV string, and/or in maximum power point tracking (MPPT) unit.***

**Key words- Photovoltaic System, grid connected photovoltaic, maximum power point tracking**

## *1. INTRODUCTION*

In this paper the analysis of fault detection in photovoltaic array with the help of fuzzy logic system is present. The fuzzy logic system depends on three inputs, namely percentage of voltage drop (PVD), percentage of open circuit voltage (POCV), and the percentage of short circuit current (PSCC). To improve the accuracy of the PV fault detection, Fuzzy Logic system is used to increase the overall detection accuracy of the power, voltage ratio algorithm up to 99.12%. fuzzy systems were tested, and it was found that have identical performance.

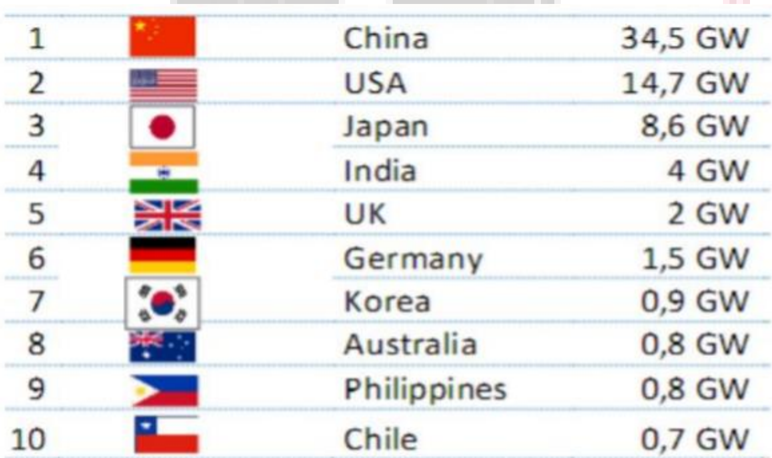
The main objective of this paper is to present research work on the design and development of a novel PV fault detection and degradation analysis. PV fault detection algorithms have been widely used to detect various faults occurring in PV installations. These algorithms relay on several parameters of PV installations such as voltage, current, power, and the series resistance of PV modules and depend on some environmental factors such as ambient temperature, and solar irradiance. However, the listed parameters are not always available in PV sites; thus, it is required to improve the existing PV detection algorithms in order to detect PV faults using fewer PV and environmental parameters [1]. However, the measured data were analyzed using laboratory-based experiments, which did not contain a real-time long-term data measurement from installed PV modules in various locations. Firstly this thesis will describe the development of various PV fault detection algorithms which are divided into three main categories: mathematical and statistical analysis algorithms, Fuzzy Logic PV fault detection systems, and ANN based systems. All these algorithms depend only on the power and voltage ratios of the PV installations. The second contribution of this work is the design of the novel PV hot spot mitigation techniques [2]. R. Hariharan et al. [1], anomalous conditions, for example, shortcomings and halfway shading lead to a decrease in the most extreme accessible power from a photovoltaic (PV) exhibit. In this way, it is important to identify incomplete shading and blames in a PV exhibit for improved framework effectiveness furthermore, dependability. H.Imanshu et al. [2], solar PV power is an untapped source of energy, thus there still remains a lot of work to be done to make solar PV system as an efficient and reliable as possible. M. N. Akram et al. [3], developed a model to describe the relationship between current and voltage of a solar cell in generation region as well as the breakdowns at positive and negative voltages. M. N. Akram et al. [4], three noteworthy cataclysmic disappointments in photovoltaic (PV) exhibits are ground shortcomings, line-to-line blames, and circular segment issues.

### *1.1 PHOTOVOLTAIC ENERGY SYSTEM*

The maximum power is delivered at the operating point, where the magnitudes of PV system and load resistance are equal. This is usually performed by an interfacing DC-DC power converter employing certain MPPT technique and algorithm. The operating point is held at MPP by regulating either the current or voltage of the MPPT converter

## *2. FAULTS DETECTION*

Photovoltaic (PV) energy has become one of the most important renewable energy resources, reaching a global accumulative installed capacity of approximately 75 GW in 2021, which is sufficient to supply 1.8% of the world's total electricity consumptions.



| | | |
|---|---|---|
| 1 | China | 34,5 GW |
| 2 | USA | 14,7 GW |
| 3 | Japan | 8,6 GW |
| 4 | India | 4 GW |
| 5 | UK | 2 GW |
| 6 | Germany | 1,5 GW |
| 7 | Korea | 0,9 GW |
| 8 | Australia | 0,8 GW |
| 9 | Philippines | 0,8 GW |
| 10 | Chile | 0,7 GW |

Figure 1: Top 10 countries in 2021 for annual installed PV capacity

As shown in Figure 1.2, the United Kingdom is the fifth leading country for annual installed PV capacity. The significant growth of the PV market has led to substantial reductions in the price of PV modules [3]. According to the annual reports published by the UK department of business, energy & industrial strategy, the majority of PV installations are sub-4 kW retrofitted schemes, which increased by 35,188 from 2021 to total of 836,014 at the end of 2022. This growth generates approximately 82 MW.

In the PV installations, fault detection analysis and protection are essential to prevent unexpected events in PV solar systems. Despite the fact that these systems have no moving parts and usually require low maintenance, they are still subject to various failures or faults along the PV arrays, power conditioning units, batteries, wiring, and utility interconnections. PV systems are scalable and modular technology can be used to build a PV power plant by connecting a large number of PV modules in multiple PV array configurations. Once PV modules are electrically connected, any fault among them can affect the entire system performance.

In large PV systems, it may become more difficult to detect or identify a fault effectively, which can remain hidden in the PV installation until the whole system breaks down. Due to faults occurring in the PV arrays, several fire hazards have been reported in PV installations. On Sunday afternoon, April 5, 2009, smoke was seen rising from the roof of a store, home to a 383 kW PV array, in Bakersfield, California [4].. However, if a return path exists in the source-circuit conductors, a 30 kW array is capable of delivering approximately 100 amps of current, which is enough to burn the conductor [5].

On the off chance that the PV framework is utilized as a part of conjunction with another force source like a wind or diesel generator then it falls under the class of half breed frameworks.

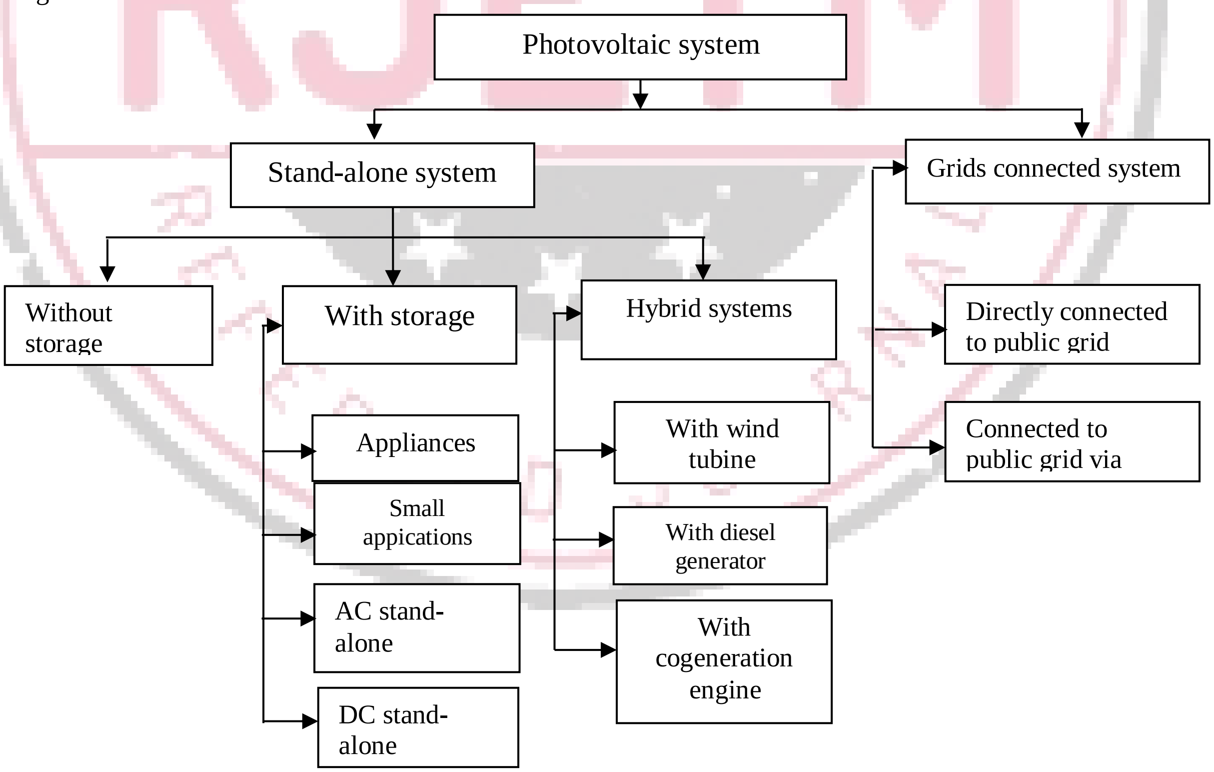



Figure 2: Classification of Solar photovoltaic systems

### *3. IMPLEMENTED METHODOLOGY*

The expansion in the vitality request requires electric utilities to build the era. To beat the issues connected with era of power from fossil fills, renewable vitality sources can be mixed in the vitality blend. One of the renewable vitality sources is the light got from the sun. A significant advantage of photovoltaic system is the use of the abundant and free energy from the sun. The sun light can be converted to clean electricity through the photovoltaic process. Despite the increasing use of PV systems, these systems still face a major obstacle due to the high capital cost and low efficiency when compared with other renewable technologies. In addition, the fluctuations in the output power due to non-linearity might lead to undesirable performance. These obstacles can be overcome by utilizing the recent technology in developing low cost PV cells and efficient power conditioning system. As a result, many research works address the development of power conditioning system in recent years with improved performances. To maximize the overall power generation of solar PV powered system, the operation point of each PV module is at its own MPP and improves converter conversion efficiency of power conditioning system.

PWM signals are pulsate sequences which are functional to the gate of switches to execute the process of converter. The pulse sequences are static frequency and level and adjustable pulse width. There is one weary of steady level in each PWM era. In any situation, the width of the thumps changes from retro to period as specified by a regulating signal. At the fact once a PWM flag is related to the entrance of a control transistor, it reasons the turn on and slays interludes of the transistor to variation preliminary with one PWM retro then onto the next PWM retro as specified by the similar changeable signal and therefore working of converter initiates. The repetition of a PWM flag essential is significantly higher than that of the adaptable signal, the major repetition, with the end objective that the strength carried to the heap depends normally on the alteration signal. The rheostat of harvest voltage is done exploiting beat width stability. The MATLAB simulated model of the explored in this work is given in Figure 3.

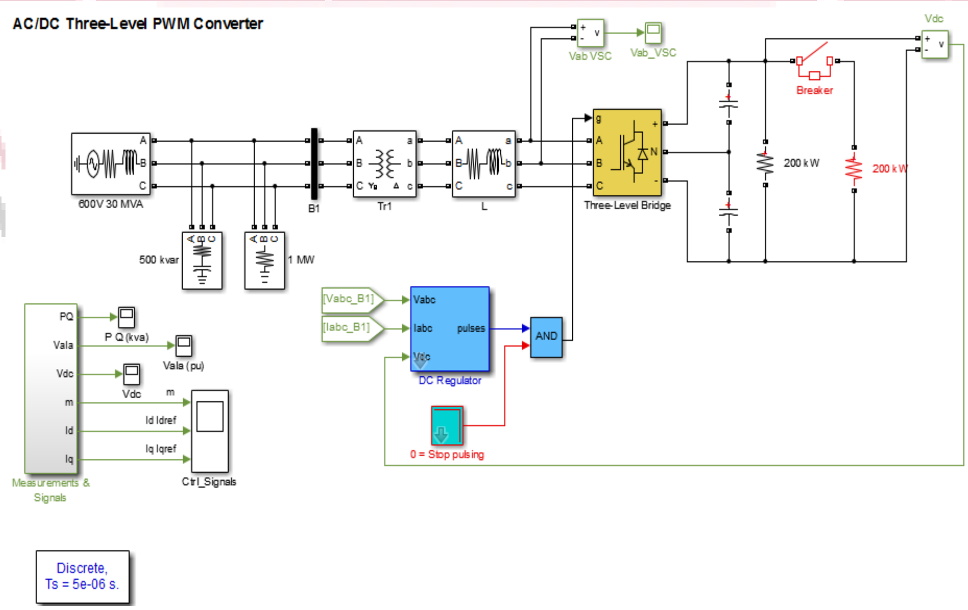



Figure 3: MATLAB Simulink Model of AC/DC Three Level PWM Converter

The photovoltaic cell output voltage is basically a function of the photocurrent which is mainly determined by load current depending on the solar irradiation level during the operation.

$$V_c = (A*k*T_c/e)\ln((I_{ph}+I_0-I_c)/I_0)-R_S*I_c \qquad (5.1)$$

The symbols used are Vc: cell output voltage, V.

Tc: reference cell operating temperature (20 °C).

Rs: series resistance of cell (0.001 Ω).

Iph: photocurrent, function of irradiation level and junction temperature (5 A).

I0: reverse saturation current of the diode (2*10-4 A).

Ic: cell output current

k: Boltzmann constant (1.38 × 10-23 J/K).

e: electron charge (1.602 × 10^-19 C).

For accurate modeling of the solar panel, two diode circuits could have been used. But our scope of study is limited to single diode model. Following are the ideal characteristics of a solar array which show the variation of current and voltage with respect to voltage which are given in Figure 4.

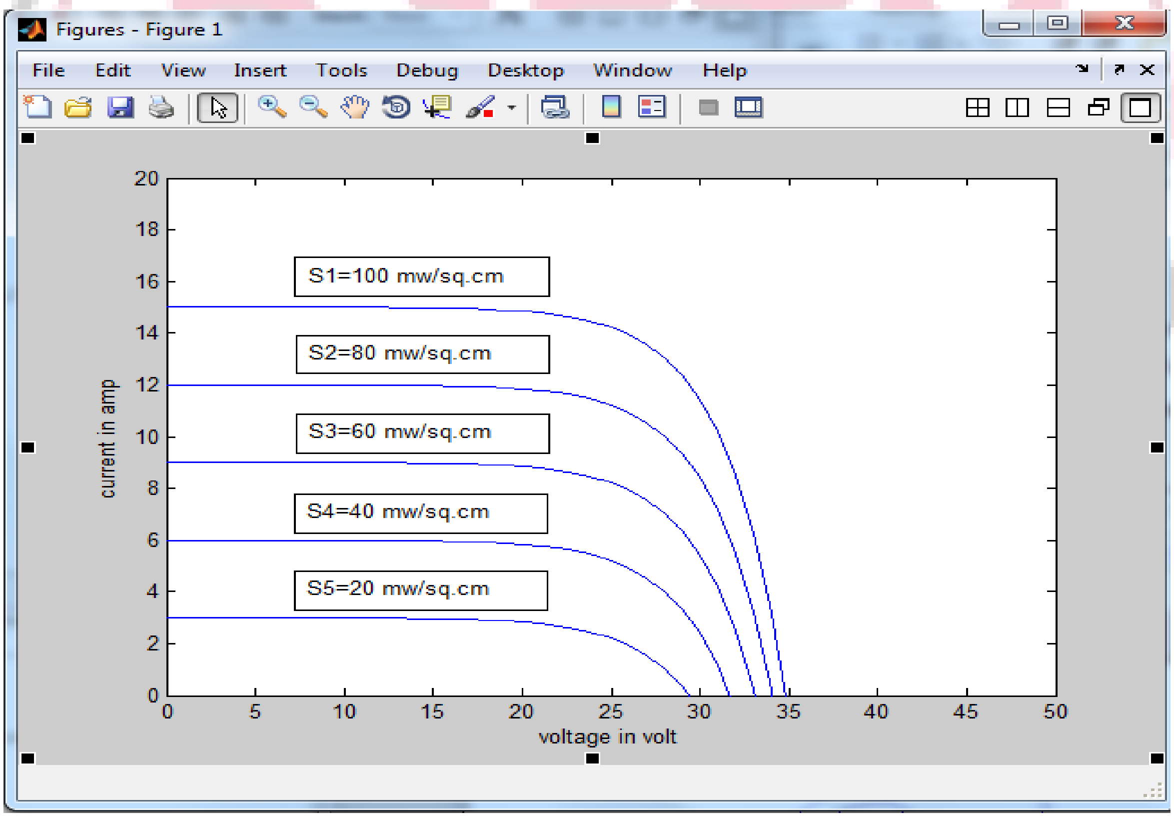



Figure 4: I-V characteristics for different insolation values

The yield of sun oriented PV cell is a Direct Current (DC), where the current is controlled by the range of the cell and measure of uncovered sun powered light. The voltage of the individual silicon cell is in the request of 0.5V. In this manner, the cell must be joined in an arrangement to constitute modules with sensible voltage level. The most extreme force is conveyed at the working point, where the extents of PV framework and burden resistance are equivalent. This is normally performed by an interfacing DC-DC power converter utilizing certain MPPT method and calculation. The regulating so as to work point is held at MPP either the current or voltage of the MPPT converter.

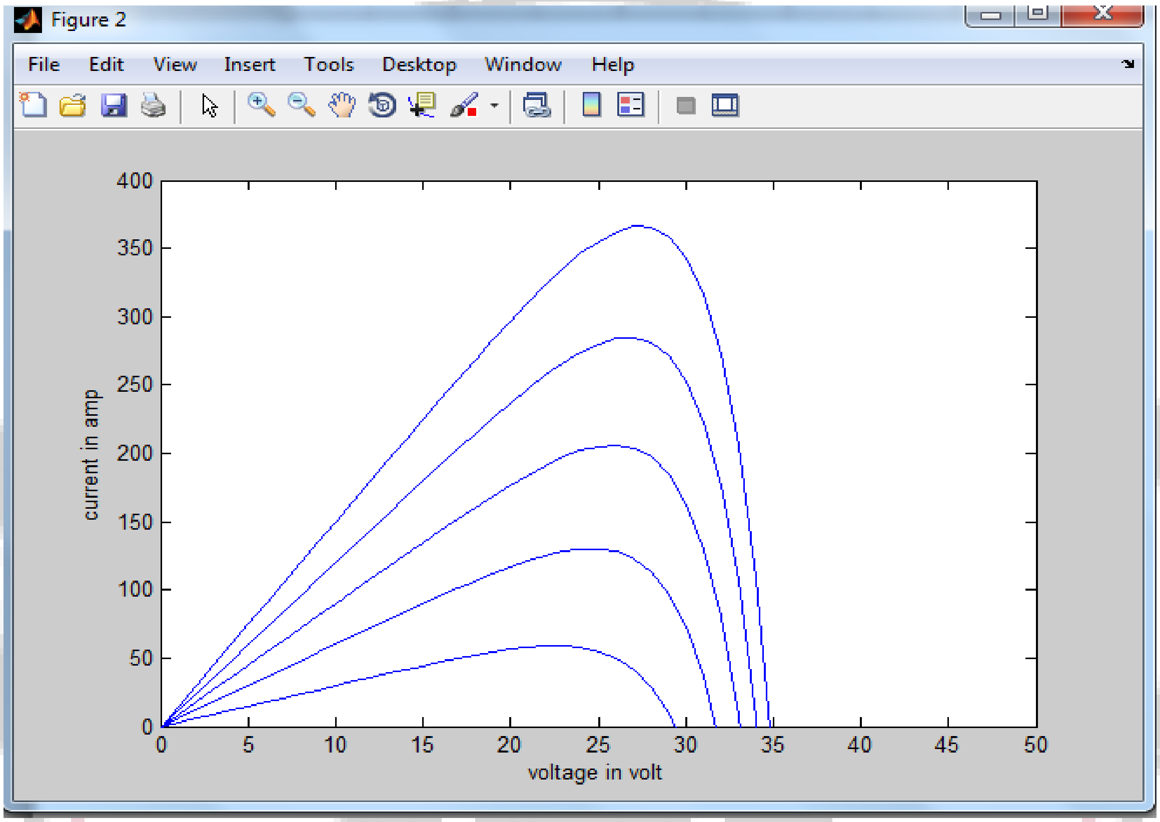



Figure 5: P-V characteristics for different insolation values

The type of power switching device (IGBT, GTO, MOSFET, or ideal switch) and the number of arms (one, two, or three) are selectable from the dialog box. When the ideal switch is used as the switching device, the Three-Level Bridge blocks implements an ideal switch bridge having a three-level topology.

### *4. RESULTS*

As shown in Table 1 the maximum power result are obtained for the proposed By-pass diode based PV array algorithm and previous algorithm. From the analysis of the results, it is found that the By-pass diode based PV array algorithm gives a superior performance as compared with previous algorithm. The proposed By-pass diode based PV array algorithm gives a maximum power 3685 for PV array.

Figure 6 shows the graphical illustration of the performance of proposed method discussed in this research work in term of maximum power. From the above graphical representation it can be inferred that the proposed By-pass diode based PV array algorithm gives the best performance for PV array omparison of power generated in previous algorithm and proposed configuration for different shading conditions

**Table 1: Comparison of power generated in previous algorithm and proposed configuration for different shading conditions**

| Reference | Different Shading Condition | Maximum Power | Total Power | Power Improvement (%) |
|---|---|---|---|---|
| Previous Algorithm et al. [1] | Side and Wide | 3097 | 4000 | 71.42 |
| | Long and Wide | 2696 | 4000 | 67.4 |
| | Short and Narrow | 3565 | 4000 | 89.125 |
| | Long and Narrow | 3227 | 4000 | 80.675 |
| Proposed | By pass Diode | 3685 | 4000 | 92.125 |

Figure 6 shows the graphical illustration of the performance of proposed method discussed in this research work in term of maximum power. From the above graphical representation it can be inferred that the proposed By-pass diode based PV array algorithm gives the best performance for PV array.

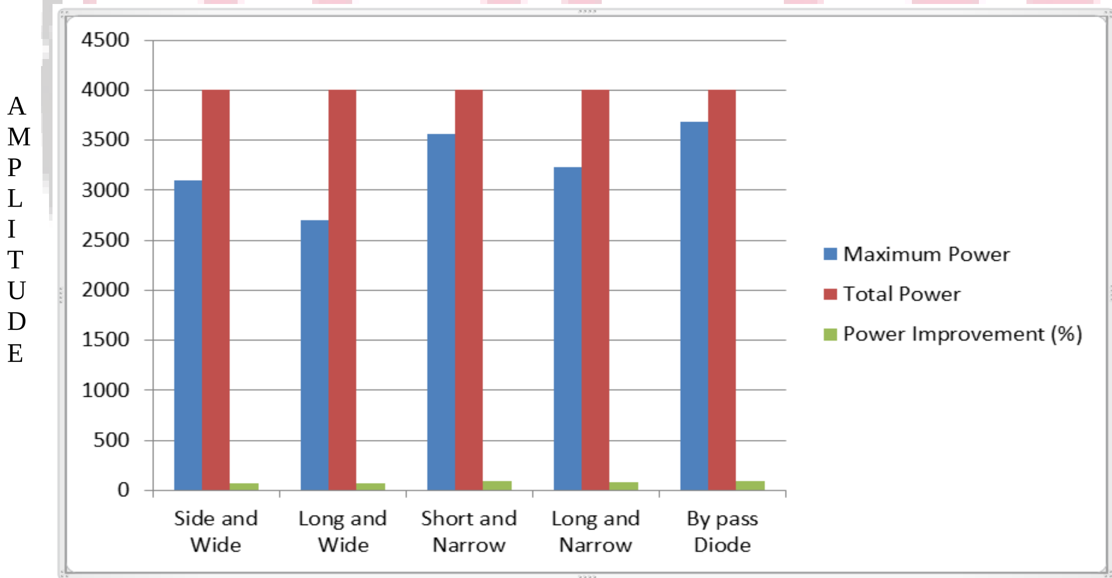



Figure 6: Maximum power for Different shading condition for PV array

***5. CONSLUSION***

The energy demand and environmental problems increases day by day in this current scenario. Natural energy sources have become an alternative to the conventional energy sources. The enormous availability of sun’s energy can be effectively utilized for the power generation using PV array. The efficiency of the solar panel varies due to variation in temperature, sun’s angle, intensity and I-V operating point.

To improve the steady state performance and converter conversion efficiency, various control methods such as zero voltage, zero current switching and chaotic PWM were implemented in Cuk converter-based solar PV system. The ripple content was examined for each method experimentally and inferred that chaotic PWM based control minimized the ripples in the output voltage and improved spectral performance of the Cuk converter based solar PV system. The proposed design will have also improved the energy efficiency of different algorithm i.e. neural network. The mathematical model to be developed in PV array with double diode and achieved maximum power. Also design the DC-DC converter i.e. cuk converter and achieved good efficiency.

***REFERENCES***

[1] R. Hariharan, M. Chakkarapani, G. Saravana Ilango and C. Nagamani, "A Method to Detect Photovoltaic Array Faults and Partial Shading in PV Systems", IEEE Journal of Photovoltaics, IEEE 2021.

[2] H, imanshu Sekhar Sahu and Sisir Kumar Nayak, "A Novel Approach to Extract Maximum Power from Partially Shaded PV Array", 2020 IEEE Power, Communication and Information Technology Conference (PCITC) Siksha 'O' Anusandhan University, Bhubaneswar, India.

[3] M. N. Akram and S. Lotfifard, "Modeling and health monitoring of DC side of photovoltaic array," IEEE Trans. Sustain. Energy, vol. 6, no. 4, pp. 1245–1253, Oct. 2018.

[4] M. K. Alam, F. Khan, J. Johnson, and J. Flicker, "A comprehensive review of catastrophic faults in PV arrays: Types, detection, and mitigation techniques," IEEE J. Photovoltaic, vol. 5, no. 3, pp. 982–997, May 2020.

[5] P. Bulanyi and R. Zhang, "Shading analysis & improvement for distributed residential grid-connected photovoltaics systems," presented at the 52nd Annu. Conf. Australian Sol. Council, Melbourne, Australia, May 8–9, 2014.

[6] M. Boztepe et al., "Global MPPT scheme for photovoltaic string inverters based on restricted voltage window search algorithm," IEEE Trans. Ind. Electron., vol. 61, no. 7, pp. 3302–3312, Jul. 2014.

[7] Y. Zhao et al., "Fault experiments in a commercial-scale PV laboratory and fault detection using local outlier factor," in Proc. 40th IEEE Photovoltaic Spec. Conf., Denver, CO, USA, Jun. 8–13, 2014, pp. 3398–3403.