ISSN(ONLINE):2278 - 3814

Volume-12, Issue-10,October 2023
JOURNAL OF COMPUTING TECHNOLOGIES (JCT)
International Journal
Page Number: 01-06

Fault Detection Analysis of MPPT Using FLC Controllers In Solar PV System:- A Review

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***Abstract*— In order to operate the photovoltaic system (PV) with high efficiency, the PV energy conversion system needs to be operated at maximum power point (MPP). It is very difficult to track the MPP as the current and power of the PV modules depends on array terminal voltage and also the MPP varies with different environmental conditions such as solar irradiance and temperature. Thus, in order to operate the PV array at its MPP, the PV system must contain a maximum power point tracking (MPPT) controller. The maximum power point tracking is achieved with conventional MPPT algorithms such as perturb and observation (P&O), Incremental conductance (INC) and also with intelligent based MPPT algorithms such as artificial neural network (ANN), fuzzy logic controller (FLC) and Adaptive neruo fuzzy inference system controller (ANFIS) and particle swarm optimization(PSO). The MPPT is integrated with DC-DC boost converter, which guarantees the DC link voltage even under changing environment conditions.**

Keywords: Photovoltaic Array (PV), Matlab Simulink, Maximum Power Point Tracking (MPPT), Fuzzy Logic Controller (FLC), Boost Converter and Fault Analysis.

I. INTRODUCTION

Signal processing is very important in many of the system At present the installed capacity of India is nearly 344.00 GW as on 31st of March 2018 of which nearly 33.23% of the total installed capacity is constituted by renewable energy sources. [1] The gross energy generation for the fiscal year 2016-17 was 1236.39 TWh with the per capita consumption of about 1122 KWh. In terms of generation India is the world‟s third largest producer and third largest consumer of electricity [1,2]. The total electricity generation with respect to resources, sector and state are as shown in the figure 1.1.

Figure 1.1: Resource wise power Generation [1]

All the data for the above tables 1.1, 1.2, is taken from executive summary for the month of January 2018. According to the report of Central Electricity Authority (CEA) total transmission capacity addition from April‟16-March‟17 to April‟16-March‟18 has been reduced by 1.96 % (in Ckms) but when compared to March‟17 in March‟18 it has increased by 32%. Whereas the transformation capacity added has risen up by 5.34% from April‟16-March‟17 to April‟16-March‟18 but when compared to March‟17 in March‟18 it has reduced by 36.4 % [1].

A. Introduction to Photovoltaic System

Solar energy is the source of energy received from the sun which provides us a platform for sustaining life on earth. Since many decades solar energy is being considered as a huge source of energy as well as an economical source of energy due to the fact that it is freely available in the universe. It is a non-conventional type of energy. However, after the continuous efforts in the field of research and technology has made it possible to capture solar energy and to convert it into the most usable form of energy. PV technologies makes proper use of the sun‟s energy and solar light to provide heat, light, hot water, electricity, and even cooling for homes and industry. Solar radiations along with the solar-powered resources such as wave and wind power, hydroelectricity and biomass, account for most of the available non-conventional type of energy on earth. Only a small fraction of available solar energy is used [4].

The sun is a constant energy source and available world-wide. It has been providing solar energy to the earth for the last 4 billion years. It is estimated that the sun supplies to the terrestrial atmosphere 10,000 times the world-wide consumption of energy during one year. Research reveals that the world solar energy demand has grown at about 25% per year over the past 15 years, while solar energy prices have declined on average 4% per year [4].

B. *History of PV System*

The rapid growth of the solar industry over the past several years have expanded the significance of photovoltaic systems which has been a prominent candidate among other renewable energy sources.

A basic physical process- the photovoltaic effect- through which a solar cell generates power from sun, was discovered in 1839 by a French scientist Edmond Becquerel. In 1954 the modern photovoltaic cell was born at bell labs in the United States. This was the first practical device that is able to convert sunlight into electricity. In 1958, the PV devices were applied to the space industry. The first satellite was launched with a PV powered system. [4]

The oil crisis of 1970s subsequently accelerated the development of this technology. In 1980, university of Delaware developed the first 10% efficient thin film made of copper sulfide and cadmium sulfide. In 1992, researches at university of South Florida broke the 20% efficiency barrier for thin film photovoltaic cells. Nowadays the PV system has been well developed and implemented in buildings, which in some circumstances can provide sufficient electric power to meet the requirement of the whole building.

C. *How PV works*

PV system use cells to convert solar radiation directly into electricity without creating any pollution as shown in fig.1.5.A typical silicon PV cell consists of at-least two layers of semi-conducting material. The layers are given opposite charges: positive and negative. The layer with positive charge is an ultra-thin layer of phosphorous doped silicon, the other with negative charge is a thicker layer of boron doped silicon. The boundary interface where P-type and N-type semiconductors are in close contact is called the P-N junction. When sunlight strikes the cell, some of the photons from the light absorbed by the semiconductors, causing light simulated electrons from the solar cells P-type negative layer to flow through an external circuit and then back into the N-type positive layer. This creates a flow of current when the cell is connected to an electric load.

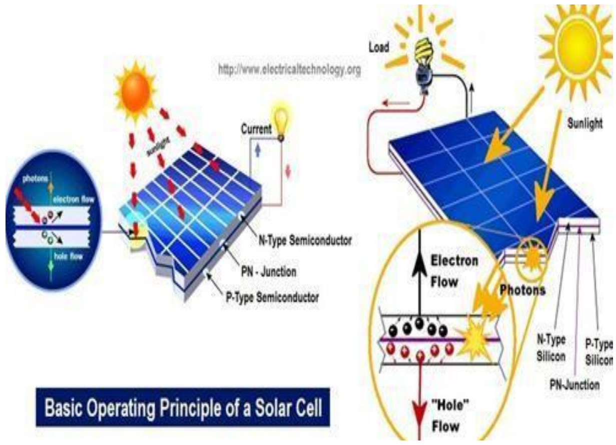

Figure 1.2: How photovoltaic cell works [4]

D. *Introduction to PV faults*

One of the primary aims of research in building-integrated PV systems is to improve the system‟s efficiency, availability, and reliability. Although much work has been done on the technological design to increase a photovoltaic module‟s performance and efficiency, there is a little research so far on fault diagnosis for PV systems. Faults in a PV system, if not detected, may not only reduce power generation and develop hot- spots, but also threatens the availability and reliability, effectively the ―security‖ of the whole system. [5]

II. LITERATURE REVIEW

Hiba Al-sheikh et al.[1]: A new technique for fault detection is presented using current and voltage values in comparison to maximum measured signal values is obtained during normal operating conditions. Specific detection zones are identified to determine the precise faulty zone. MATLAB software was used to simulate it also we present the results under worst-case scenario faults which is the case when all branches are faulty simultaneously. Involves fewer voltage sensor than current models. This method has the ability to detect and localize the hot-spot even when only 10% shading was imposed. This combination is important for solving worst-case scenario faults.

Himanshu Sekhar Sahu et.al. [2]: Calculation for reduction in efficiency of faults associated with solar PV cell and modules are analyzed. Beside this different fault detection procedure are also discussed that are adopted worldwide. The aim of this paper was to quantify the loss ofproduction and efficiency as well as to assume the fault level approximately by mathematical modeling if a fault starts to develop. Moreover, for accurate detection of faultsdifferent standard PV module testing procedures that are used worldwide are also discussed. By knowing the effect of faults, scientists can develop more fault resistant PV modules having higher efficiency and develop alarm systems as and when fault associated loss occurs.

Alonso-Garcia et.al. [3]: It proposes a simple automated technique for fault diagnosis in PV arrays, based on the analysis of anomalies observed in the I-V characteristics. Subsequently, the I-V characteristics of the PV string under different fault scenarios are compared, in order to identify the anomalies. Finally, six categories are generated: Normal operation, connection fault, connection fault with shadow effect, partial shadow fault, a group of fault which include shadow effect with faults on bypass diode (open circuit bypass diode, inversed bypass diode, shunted bypass diode), and a group of fault which include: bypass diode fault, cell fault, module fault, and shadow effect with shunted by pass diode fault. This paper investigated a fault diagnosis technique for photovoltaic string, based on the I-V characteristic analysis.

R. C. N. P. Podgurski et.al. [4]: In order to elevate the availability of solar energy to uplift the system‟s total efficiency, solar power systems generally are equipped with the function of maximum power point tracking (MPPT). The existing algorithms of MPPT include the voltage feedback method, the power feedback method, the incremental conductance method, the perturbation and observation (P&O) method, artificial neural network method, fuzzy logic methods, and the three-point-weighting method. The voltage feedback method compares the PV output voltage or current with the voltage or current on the maximum power point, MPP, based on a given I-V or P-V curve of the PV cell, using the single voltage or current feedback to make the system operate at the MPP by the rule of voltage control.

C.Neeb et.al.[6]: Developed a circuit-based simulation model of a photovoltaic panel using the PSIM software package and also compared the field test data to the simulated results. A 3kW PV array system was established using the PSIM to conduct the fault analysis and then proposed an extension diagnosis method was proposed based on the extended correlation function, which is one of the main theories in extension theory, to identify the different fault types of the PV system. The simulated results indicate that the proposed fault diagnosis method can detect the malfunction types correctly and promptly.

S. Yang et.al. [7]: Used earth capacitance measurement to locate faults in PV module arrays. Through the comparison of the earth capacitance value between the fault string and the good one, the disconnection position within the module strings can be estimated. This detection method can be used anytime to locate the fault position in the string due to earth capacitance without the effects of the irradiance change. Moreover, this method is easily affected by the installation circumstances such as wiring, mounting the modules, or mounting materials.

E. Ribeiro et.al. [9]: Modeling and detection of the hybrid defects, like the presence of open & short circuit of the cells within the same photovoltaic cells group are reserved in it. It proposes a new algorithm to model the PV module under healthy and faulty operation which is capable of ensuring a better modeling and detection functions, of the four modules operation modes; normal operation, operation with short-circuit cells, operation with open-circuit cells, and particularly operation with cells short and open circuit hybridization. The future work of this algorithm is intended to improve more its performance, for increasing more the detection rate, and also for reducing more the detection error.

Alonso-Garciaa et.al. [10]: Experimentally studied two methods to locate the fault in PV module strings. One was the earth capacitance measurement (ECM), which uses the earth capacitance value to estimate the disconnection position between the modules. The other was time-domain reflectometry (TDR). Through this method, the degradation such as increase in series resistance between the modules and the fault position in the string can be detected by the change of response waveform.

Azab, M et.al. [11]: Developed a diagnostic technology for PV systems based on statistically analyzed data. This study used diagnostic criteria databases to analyze data acquired from the PV systems and used them to detect shading effect and inverter failure in PV arrays. This method can detect possible problems with the configuration of the PV system; however it cannot detect the exact fault position in the string.

Benavides[12]: The output characteristics in a faulty PV array were determined by using a fault simulation PV system. Three fault detection methods are discussed, Method 1: Comparison of measured output value and estimated value derived from measured irradiation. Method 2: Comparison of present and past performance ratios (PRs). Method 3: Comparison of present and past output differences in an intersystem. This study discusses how accurately the system detects PV module faults.

III. OBJECTIVE AND METHODOLOGY

In order to minimize energy losses& maximize the efficiency in installed PV systems, the diagnosis and monitoring of PV system plays a very important role. The output power generated by a PV system depends on the irradiance and the surface temperature of PV cells. If some faults exist in a PV system which result in lower power output, users may attribute this decrease to low solar irradiation or other changing condition rather than a fault condition. Even if users know that the PV system has a fault condition, but they may not able to identify or detect which fault it possess, nor have a method to determine what fault is present.

The objective of this thesis is to develop the fault diagnosis technology to detect PV system faults. This research deals with developing guides and benchmarks for some specific and common faults in PV systems to assist users in identifying the different faults in PV systems. Moreover, maximum power point tracking techniques are applied in order to maximize the output power as well as efficiency of a PV system.

IV. PV MODELLING

A. Introduction to the PV model development

A model of a PV system is created using MATLAB/Simulink in order to understand the performance of the PV system, as per the descriptions jotted in table 4.1. This MATLAB/Simulink model clearly illustrates current produced by the sunlight, DC power generated byPV panels, and a DC-DC converter connected to the PV array output as a front-end converter to track the MPP and adjust voltage and then is fed to a DC-AC inverter. Therefore, the available AC power can be supplied to the load. The PV system can be divided into several smaller subsystems including a PV array, maximum power point tracking (MPPT) controller, a DC/DC converter, an inverter and several switches controlled by pulse-width modulation (PWM), etc.

B. A PV array model development

Basic principal of the PV cell

The equivalent circuit of a PV cell, as shown in Figure [4.2], shows a good correspondence to the electrical behavior of the actual cell. This circuit consists of an ideal current source Ip generated proportional to the solar insolation level and to the cell surface temperature, an ideal P-N diodeDj , a large shunt resistance Rs connected in parallel with the current source and a very small series resistanceRs. I d and Is are the diode current and the shunt resistance current, respectively. V and I are the output voltage and output current of the solar cell.

C. Boost DC/DC Converter Model Development

Basic Operation Principal of the Boost Converter A Boost DC/DC converter is used to step up the output DC voltage supplied by thePV array and provide a control actuator to MPPT using pulse width modulation (PWM) control on switches. A simplified Boost converter consists of two semiconductor switches (a diode and a transistor) and one energy storage element(capacitor). A simplified diagram of a boost converter is shown in fig. (4.1).

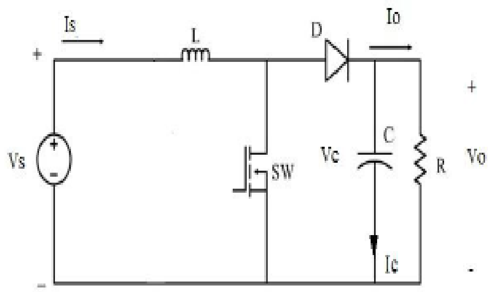

Figure.4.1- Boost converter circuit diagram

There are two basic principles of a Boost converter, depending on the state of the switch: the On-state and the Off-state, as shown in Figure (4.6).During the On-state, the switch S is closed, and then the input voltage is connected to the inductor L, and the current flows the inductor from the PV array, thus the inductor is charged; During the Off-state, the switch S is open, and then the inductor current flows from power supply through the inductor L, the diode D, the capacitor C and the load R to recharge the output capacitor, resulting in transferring the energy generated during the On-state to the energy storage element capacitor.

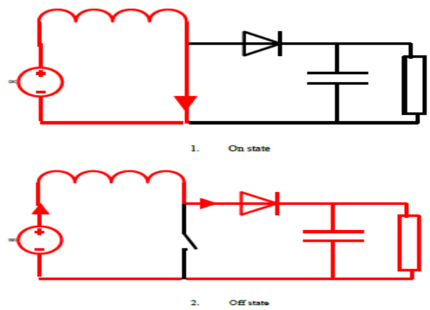

Figure 4.2- The two configurations of a Boost converter

D. Model Development of PV parameters **Phase current**

$$Ip = [(Top - Tref\ ) Ki + ISC\ ] Irr$$

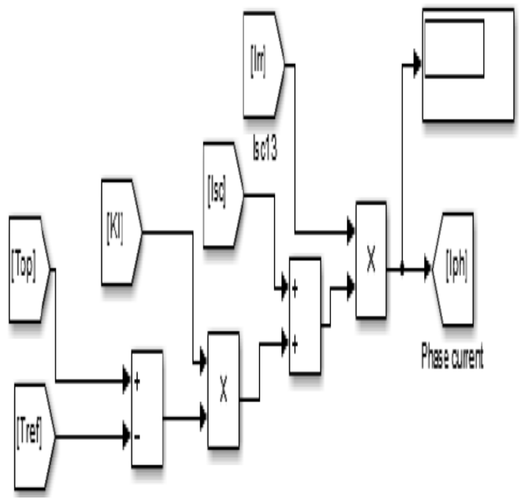

Figure. 4.7- Model development for calculation of phase current

Diode current

$Id = Np\ IS$ [exp {(V / NS + I NS /RS) / nVt C}-1]

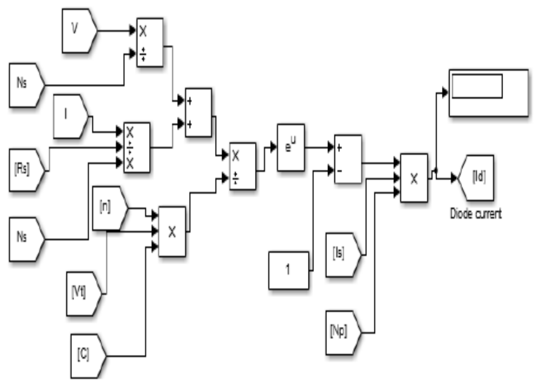

Figure 4.8- Model development for calculation of diode current

Saturation current

$Is = Irs\ (Top / Tre\ )3$ exp {q Eg / k n (1/Top -1/$Tref$)}

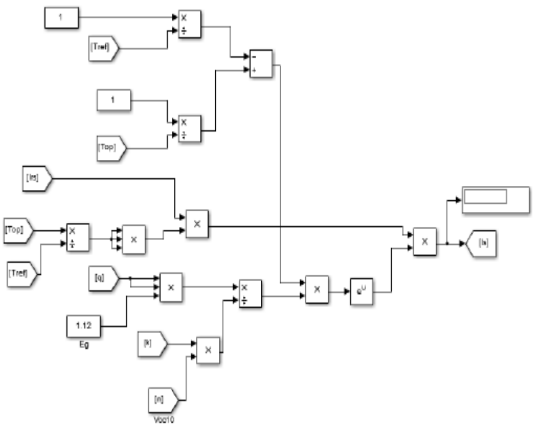

Figure.4.3- Model development for calculation of saturation current

Load current

$I = Np\ Ip - Is - Id$

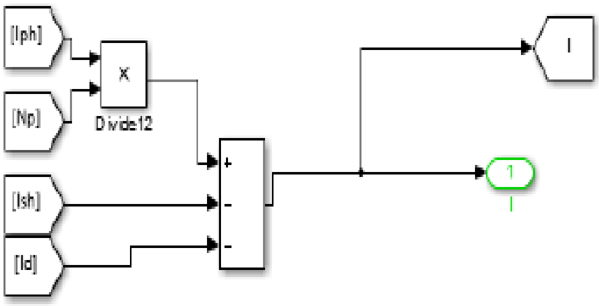

Figure.4.10- Model development for calculation of load current

Reverse saturation current

$Irs = Isc / [\exp \{q\ Voc / k\ C\ Top\ n\} - 1]$

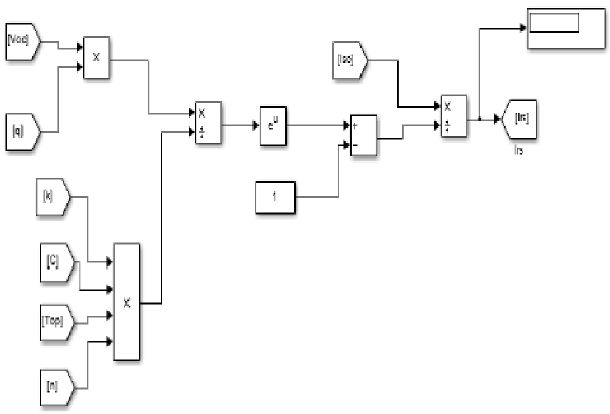

Figure.4.11- Model development for calculation of reverse saturation current

V. CONCLUSION AND FUTURE SCOPE

Due to the exponential increase of PV systems, throughout the world, it is increasingly important to develop new PV fault detection techniques, in an attempt to increase the systems‟ performance and lifetime. With that said, numerous new tools have been hitting the market recently, which allow the detection of the system‟s various parameters and emit alerts when their current production is below a certain threshold.

In this dissertation open circuit fault as well as short circuit fault conditions are analyzed. The simulation results depicted reduced output power due to the presence of faulty conditions. So to get rid of this drawback maximum power point tracking techniques basically perturb & observation techniques was applied in conjunction with MPPT controller. Both proportional integral (PI) and fuzzy logic controller (FLC) were developed using the specific algorithm. Finally, the handling of data takes place in different ways – one of them calculates the data using normalized power values and the other calculates them using the power loss values. In the end, after comparison of result‟s from the obtained simulation graph‟s the output power across the load using PI as well FLC controller concluded that, minimum power loss occurs in the case of FLC controller even when open circuit and short circuit fault‟s persist.

A thorough analysis of the developed system‟s behavior is observed to determine the system‟s performance involving two different MPPT controller. Looking at the results, we saw that the reduction in output power reaches to a slightly low value in case of FLC controller, when compared with the results of PI controller. Also, the analyses were made under the prevailing faulty scenario.

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