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Performance Analysis of FLC MPPT for Standalone Photovoltaic System

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Abstract:

This paper presented the performance of Fuzzy Logic Controller based MPPT for standalone PV system. The traditional perturbation and observation (PO) MPPT method is incapable of rapidly acquiring the maximum power point (MPP), and the tracking course is extremely difficult under unfavorable weather circumstances; however, the reason for this is unknown. Due to their ease of application and excellent tracking efficiency, incremental conductance techniques are commonly employed. The MPP is not known on the V-I or V-P curves, but it can be found using search algorithms such as perturbation and observation (P&O) and incremental conductance (InC). In this paper, an FLC algorithm is proposed for tracking an MPP on the V-I characteristic of a solar PV panel. Using Matlab Simulink software, the simulation results can be used to validate the effectiveness of the proposed work under various atmospheric conditions.

***Keywords* — PV system, MPPT, FLC, Irradiation**

I. INTRODUCTION

Solar power is widely recognized as one of the most significant forms of renewable energy.Solar energy, in contrast to more traditional resources like gasoline and coal, is not only free but also environmentally friendly and infinite.The V-I characteristic of solar cells is nonlinear and changes depending on the irradiance and temperature of the cell. In most cases, there is a single point on the V-I or V-P curve that is referred to as the Maximum Power Point (MPP). This point is the location at which the complete PV system (array, converter, etc.) functions at its highest level of efficiency and generates the most amount of output power. The precise location of the MPP is unknown; however, it is possible to find it by utilizing either mathematical models or search algorithms. Techniques known as Maximum Power PointTracking (MPPT) are required because of this in order to keep the operating point of the PV array at its MPP.In the research that has been done on MPPT, numerous techniques have been proposed. Some examples of these techniques include the Perturb and Observe (P&O) methods [4-7], the Incremental Conductance (IC) methods [4-8], the ArtificialNeural Network method [9], the Fuzzy Logic method [10], and many others. These methods differ from one another in a variety of ways, including ease of use, speed of convergence, ease of hardware implementation, number of sensors required, cost, usefulness across a range of situations, and requirement for parameterization. The P&O and IC approaches, in addition to their respective offshoots, are the ones that see the most usage.

These currently available algorithms each have a number of benefits and drawbacks, including simplicity, convergence speed, additional hardware requirements, and overall cost. An improved version of the InC algorithm is proposed in this thesis as a means of monitoring an MPP on the V-I characteristic of a solar PV panel. As a result of the ST and MPPT, the solar photovoltaic panel is always guaranteed to operate in a situation that is both adaptable and optimal for any given set of circumstances.

The goal would be to create MPPT and successfully apply the MPPT algorithms utilizing the Simulink models as the primary tool. It would be of the utmost necessity to model the photovoltaic system and interface with the MPPT algorithm in order to find the operation that provides the maximum power point. The findings of detailed simulations that were carried out to support the same have been reported here. The simulations were carried out in MATLAB.

II. SOLAR PHOTOVOLTAIC

Photovoltaic (PV) is a highly important and prospective energy source because it offers very clean energy without having any effect on the environment. This makes it one of the most promising of all the renewable energy sources. Sunlight, which makes up the solar energy supply, is a source of energy that is both abundant and cost-free. However, as of right now, solar photovoltaic (PV) modules have a relatively low efficiency level when compared not only to the efficiency of conventional fossil fuel but also to the efficiency of other renewable energy sources such as wind or hydro [1–4]. This is due to the fact that solar energy is still in its infancy as an energy source. It is considered to be a very hot development field to improve the efficiency of PV systems by tracking the global maximum power from PV systems both with and without partial shading situations.

In order to obtain high voltage and current output, a PV module is constructed comprised of PV cells connected in series and parallel. The common technologies for photovoltaic cells can be broken down into four categories: multi-crystalline, mono-crystalline, thin-film, and multi-junction PV cells. Each every type of photovoltaic cell technology has its own distinct production method and set of properties. PV models are utilized in order to draw conclusions regarding the output PV characteristics under a variety of irradiance and temperature situations for the purpose of investigating and studying the performance of the PV system. In most cases, the photovoltaic (PV) model will include a photocurrent source, diodes, and resistors.

It is absolutely necessary to carry out the measurements in accordance with the specified test circumstances in order to obtain accurate readings of the I-V characteristics (STC). This indicates that the total irradiance that should be measured on the solar cell is equivalent to 1000 watts per square metre. In addition, the temperature of the solar cell should be maintained at 25 degrees Celsius at all times.

The PV panel is modeled using the equation (1)

$$I = I_{SC} - I_0\left(e^{\frac{q(V+IR_S)}{KT}} - 1\right) - \left(\frac{V+IR_s}{R_p}\right) \qquad (1)$$

Where,R_s and $R_p$are the resistances used to consider the impact of shading and losses. Although, the manufacturers try to minimize the effect of both resistances to improve their products, the ideal scenario is not possible.

It has been shown that solar photovoltaic panels are extremely sensitive to the effects of shade. Because of this, an analogous circuit that is more accurate for the solar PV cell has been developed. This circuit takes into consideration the impact that shade has, as well as losses that are caused by the cell's internal series resistance, contacts, and interconnections between cells and modules.

Irradiation and temperature are, without a doubt, two critical aspects that must be taken into consideration in the process of calculating the amount of power that may be produced by a solar photovoltaic panel. These parameters have a significant impact on the properties of solar photovoltaic panels. Therefore, the solar PV panel needs to be oriented such that it is perpendicular to the sunlight in order to obtain the maximum amount of irradiation.In addition, as a consequence of this, the MPP shifts during the day, and it is vital for the solar PV panel to track the MPP in all conditions in order to guarantee that the greatest amount of available power is obtained. The MPPT algorithms are responsible for searching for and determining MPPs under a variety of different scenarios in order to solve this problem.

III. MAXIMUM POWER POINTTRACKING METHOD

A maximum power point tracking controller, or MPPT controller, is a type of controller that monitors the maximum power point locus of a photovoltaic array. There are a few standard maximum power point tracking algorithms that have been discussed here, and there are a few other algorithms that can track the MPP. In order to ensure the most efficient functioning, the line of the load must be aligned with the MPP locus of the PV array. Furthermore, if the load in question does not consume the maximum amount of power, a power conditioner should be installed between the array and the load.

The MPPT technique known as "perturb and observe" is arguably the one that is used the most [24]. P&O is predicated on the idea that one should continuously disrupt or change the working point of the power converter, and then one should observe or sense the impacts of these changes. In other words, the parameters within the converter are altered in order to effect a change in the voltage and current output of the solar panel. The voltage and current of the panel are then measured by the system to determine whether or not the panel's power has grown or decreased. The algorithm then arrives at a conclusion regarding the best way to make additional adjustments to the settings of the converter. In most cases, the adjustments that are made are to either a reference voltage or a duty cycle.

Both P&O and Hill climbing utilise the same core strategy. The perturbation in hill climbing is represented by the duty ratio, whereas the perturbation for the P&O is represented by the voltage of the PV module. Altering the value of the duty cycle will result in a change to the current, which will, in turn, cause the voltage array to be disturbed. To recap, if the power increases as a result of a particular perturbation, the subsequent perturbation should not change; on the other hand, if the power decreases, the subsequent perturbation should move in the other way.

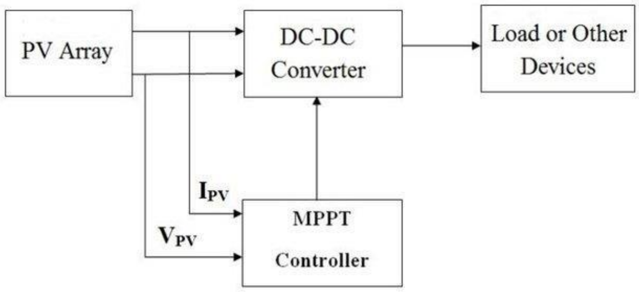

Fig. 1: General Block diagram of MPPT

The voltage and current are both measured in Fig. 1, and the MPPT controller uses both readings to establish the voltage reference.

The problems that are inherent in the Perturb and Observe approach are resolved by using the Incremental conductance method. It takes use of the fact that there is no change in the power's derivative with respect to the voltage while it is at its maximum power point. In addition, the derivative is negative to the right of the MPP while it is positive to the left of the MPP. This means that the derivative cannot equal zero.

The incremental conductance algorithm comes with a few benefits as well as a few drawbacks in its package. For example, IC has the ability to latch on to the MPP. In other words, once it determines where the maximum amount of power can be extracted from the system, it stops agitating the system unless the conditions shift. Because of this, the input to the converter, as well as the output it produces, become steadier and more continuous. Even though the algorithm is more intricate than

P&O, it is still not too difficult to comprehend. In addition, in the same way as P&O does, this algorithm necessitates the measurement of both the voltage and the current. In comparison to P&O, the IC algorithm has a significantly higher demand for the amount of processing and reasoning that must be performed. This is an obvious disadvantage of the IC method. In addition, similar to the P&O algorithm, this one also has the potential to command the incorrect perturbation, but for a somewhat different reason.

The FLC has found widespread use in MPPT for photovoltaic (PV) systems, which allows for improved performance compared to traditional techniques of calculation.

the primary stages of FLC systems are the fuzzification stage, the fuzzy inference engine, and the defuzzification stage. These three stages are all interconnected. In the stage known as fuzzification, the variables of the crisp inputs are changed to linguistic labels in accordance with the input MFs that have been predefined. In the initial stage of the process, the converted linguistics labels are used as fuzzy input to generate spoken decisions. In order to produce a fuzzy output, the fuzzy inference engine makes use of the fuzzy inputs, and it does so by using the concept of 'if-then rules.' In the third stage, the resulting fuzzy outputs are turned into values with a higher level of precision. In FLC systems designed for use in MPPT applications, one output is generated using a combination of two inputs. This allows the system to function in the MPP mode.

The fuzzy logic controller (FLC) utilises the selected fuzzy relationship in order to map the significant and measurable variables to the controlled variables when performing a control job. After being processed, the defuzzification output is typically passed back to the fuzzification interference in the form of crisp or non-fuzzy input. Error and variations in error are mapped with fuzzy sections, and these are included in the crisp input. The output variables that have been altered are made accessible at the defuzzification stage for use as input to the procedure.

IV. SIMULATION RESULTS AND DISCUSSION

This section will highlight extensive simulation findings of the proposed solar photovoltaic system employing improved InC MPPT, and those results will be compared to those obtained using traditional MPPT.

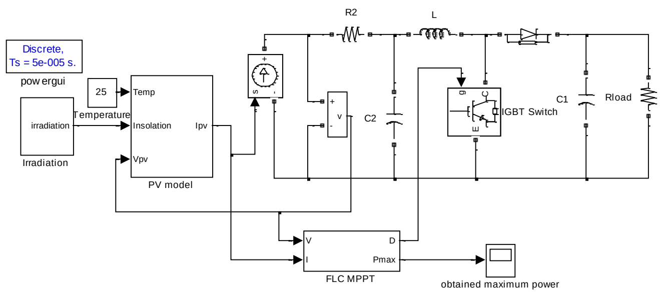

Fig.2: Matlab Simulink model for standalone PV system using FLC MPPT

The simulated system may be found depicted in Fig.2, and simulation studies are performed in the environment provided by MATLAB and SIMULINK.

The solar PV panel provides a maximum output power at a MPP with V_{MPP} and I_{MPP}. The MPP is defined at the standard test condition of the irradiation, 1 kW/m2 and module temperature, 25°C but this condition does not exist most of the time. The following simulations are implemented to confirm the effectiveness of the FLC which is compared with those of the InC, improved InC algorithm and P&O algorithms. Matlab Simulink block diagram is shown in Fig, 2.

The variation of both irradiation and temperature is shown in Fig.3. The obtained output powers are shown as in Fig. 4 & Fig. 5 using the P&O, InC, improved InC algorithms and FLC under the variation of both the temperature and solar irradiation. It can be realized that the simulation results of the cases using the FLC are always better than the cases using the P&O, InC algorithms, improved InC algorithm.

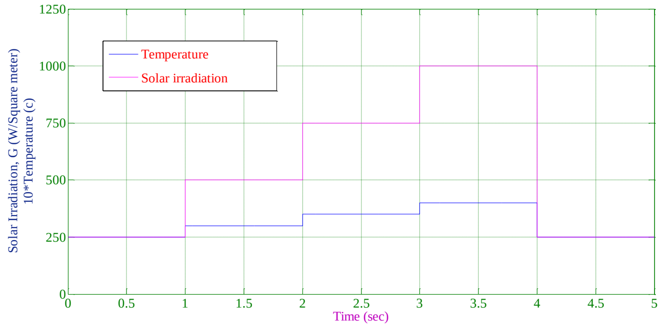

Fig.3: The variations of the solar irradiation and temperature

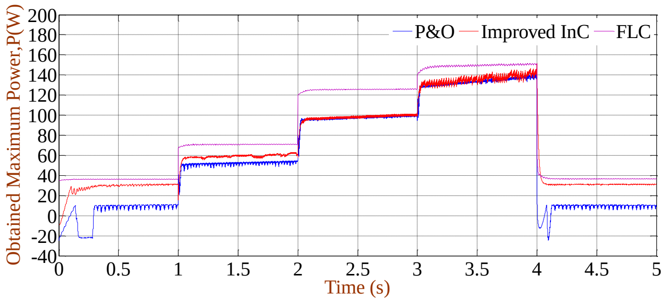

Fig.4: OMP with the P&O and improved InC algorithms under both the variations of the solar irradiation and temperature

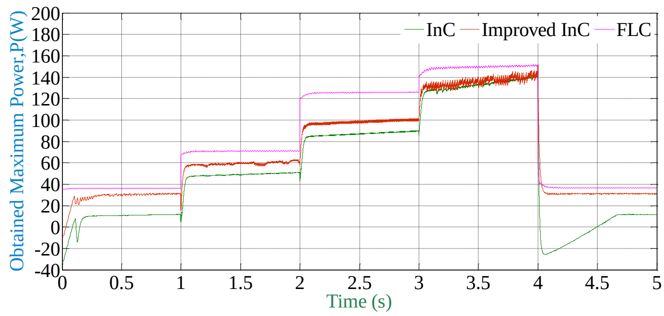

Fig.5: OMP with the InC and improved InC algorithms under both the variations of the solar irradiation and temperature

V. CONCLUSION

In the context of this paper, the adaptive and optimum control approach is given a significant part to play in the process of developing solar photovoltaic (PV) systems. This strategy is based on the combination of the ST and the MPPT in order to ensure that the solar PV panel is capable of capturing the maximum amount of solar energy following the trajectory of the sun from dawn until dusk and is always operated at the MPPs with an improved algorithm for the inductance control. This strategy was developed in order to ensure that the solar PV panel was able to do so. The conventional InC algorithm is made better by the proposed InC algorithm thanks to an approximation that reduces the computational burden, as well as the application of the CV algorithm to limit the search space and increase the convergence speed of the InC algorithm. Both of these improvements were made possible by combining the two algorithms. This enhancement eliminates the deficiencies that were previously present in the InC algorithm. Validation of the FLC control technique in the solar PV panel was accomplished through simulation studies by comparing it to several other control systems.

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