THE FUZZY LOGIC CONTROLLER MODEL FOR INTEGRATION OF PV SYSTEM INTO THE UTILITY GRID

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Abstract- This paper presents the fuzzy logic-based controller model for the integration of the photovoltaic system into the utility grid. Recently, the photovoltaic (PV) generation is growing fast as an effective and cheap energy source. In any PV based system, the inverter is an essential part, which is capable of regulating the current flow between the grid and DC. However, the problem of the integration of PV is that it relies on weather conditions. Therefore, there is a necessity for developing control techniques for the grid integration PV system including a method for voltage and current control that stabilizes the voltage and current at the inverter input to guarantee a continuous flow of energy among the grid and the PV system. This paper presents control and simulation for the integration of the PV system into a grid using MATLAB/Simulink. The PV integration is connected to the boost DC/DC converter and the controller system is based on the maximum power point tracking (MPPT) with a fuzzy logic based controller that helps PV to ensure the maximum power in case of fluctuation in the weather, and then integrated into the AC utility grid by DC/AC inverter. The system stability tests for different weather conditions in the PV system. This paper advocate that the proposed fuzzy logic controller gives a good performance over regular control methods.

Keywords: The PV system, Fuzzy logic controller (FLC), Boost converter DC/DC, Maximum power point tracking (MPPT).

1. INTRODUCTION

Generated power from RES is on the increase in developing countries. They try to improve the integration of renewable energy generation into the grid by using hybrid power energy PV and wind energy, the storage is important by using the battery. There is a necessity to address the problem faced by the grid integration of hybrid energy, so a result of the intermittent nature of the use of renewable energy resources. The developed countries used to predict several techniques to predict solar radiation and wind speed for a significant period [1]. The world is looking for alternative energy methods from renewable energy for clean and cheap energy that will get rid of the dependence on costly oil and also gas.

Generating electric power by using solar cells is an effective technique nowadays. The various local voltage control approaches utilizing PV storage systems. This design center on adding a voltage control ability to self-consumption plans by a set of voltage following battery charging, automatic reactive power equipment like PV power reduction. [2]. At this time, the researchers are interested in the generation of electric power from renewable energy and the most focused on solar energy, Solar energy (PV) can be used today in many applications now because of where advantages such as pollution-free and can be maintained. The high cost of oil and gas has weakened the economies of several countries. Since solar PV is capable of generating large amounts of clean and chip electrical energy. It can be connected to the inverter to the electricity produced from PV to be used for the conversion of DC power from PV to AC power to feed the electrical grid [3].

The efficiency of MPPT maximum power point tracking depends on the quality of an inverter. To increase the performance of the PV panel and the inverter is not easy it mostly depends on the available technology, the best components can increase the cost of installation this is a problem, the control. It will develop the tracking of the maximum power point so it will immediately increase in PV generation of power and reduction in PV price. The control of MPPT is necessary because of the non-linear V-I characteristic in the PV array when the power generated is maximized. The MPPT relies on the irradiance conditions and the temperature of the panels. It can be both conditions change amid the day and rely upon the period of the year [4]. They gave the Altaeros system's dynamical paradigm after that addressed how that paradigm is utilized in the plant outline, the design of the control, which gives full self-governance, from departure, amid force generation, to self-governing landing. The provided simulation results illustrate the behavior of the model and indicate critical ranges where Altaeros will center its endeavors advancing [5].

The control technique is to integrate the distributed generation (DG) resources into the utility grid. The designed controller can be compensated for reactive, active, and harmonic load current components while the linkage of DG links to the power grid. The performance of the control method in distributed generation enforcement is demonstrated by adding the maximum power from the distributed generation to the grid, while, the rise of the power factor of the grid also, decreased total harmonic distortion of grid current in simulation and real-time situation under relentless status and element working cases [6]. The reliability of the system when the PV plant is linked to the grid is strengthened when the power factor, the utilization of safety, and grid synchronization capabilities functions are improved. Development in the efficiency of photovoltaic cells and low price make

them widely accepted and concentration in the entire world and not to rely on non-renewable energy sources, the most important advantages we have electrical energy through clean renewable energy.

The power plants in recent times need to increase their energy output, need appropriate control methods to resolve the issues associated with the partial shading phenomena and different orientation of the PV modules closer to the solar [7]. The evolution of the grid-connected Large-scale power plants because of the increasing penetration of renewable energy. The control approach can reduce the reactive power beside it can control the power quality required by a voltage sag/swell for the stability of the grid. This approach does not require any change in the hardware when compared with the employ of the existing strategy [8]. The photovoltaic (PV) systems were designed to aim until now, to get the superior power from the PV and integrated into the utility network.

Therefore, the MPPT of a uniformly irradiated PV array and the main design issues is the increasing of the conversion effectiveness. However, when the PV system is linked to the grid, a great observation of the power quality, the reliability of the system and the use of security and grid synchronization functions have to be considered. Nowadays the power plants need their power generation, requiring appropriate control technologies to remedy the issues related to the PV modules toward the sun. The numerous important issues, which include the maximum dependable models, used for simulation, were covered, which are helpful in the controller design and the MPPT function, particularly in distributed applications. The grid linkage fields are studied, confirming security, integration, and synchronization [9].

A solar array (PV), and wind energy are a principal supply for the grid, but the use of fuel cells in some cases is a backup power source if there is no generation of electricity from hybrid sustainable energy. Hence, the use of hybrid renewable energy to supply the power it most requires power-storing devices. So the battery energy is used for storing the power and it can use anytime with three various power management strategies [10]. Although a solar PV system model a good choice, as in a critical era of low energy system performance, energy conversion good needs energy conversion performance of the system. This should differ MPP experienced by the maximum possible power transfer to the load can be changed. Although, the study in this area provides the availability of different techniques. Every one of them has its advantages and disadvantages. This status everywhere in the possible (MPPT) discovers the complexity of its time choice [11]. A Fuzzy logic controller based on hybrid renewable sources (HRS) for Grid integration is observed to be more outstanding & enough to decrease power quality problems subjected to all Non-Sinusoidal conditions [12].

The grid integrated a hybrid model, it gives wind energy and PV as a major energy and a storage system depends on the battery storage. Total power energy utilizes DC/DC converters required to integrate hybrid to the DC line [13]. The photovoltaic inverter residue inactive through the evening or in minimum solar radiation. Massive hard works by academics to beat the problems related to renewable energy as the PV system and wind system by suggesting more advanced and accurate control applications, containing a lot of hybrid energy topology simple power but are just proper for applications stand-alone [14]. PV systems including a battery show that in which both sources are integrated into grid combined DC bus by different power converters, next, the grid transmission line is integrated into the network by an inverter [15].

In this paper, good control and simulation model of PV is given with a clear idea of the appropriate control FLC system and behavior of an actual system with change time during the day that can be utilized to investigate the performance of the PV system. The control is advanced and simulated in Matlab/Simulink program and the performance consequences depicted it's well worth.

2. MODEL OF SOLAR PV SYSTEM

The Solar PV system scheme includes the demanded quantity of PV cells, it is referred to as PV module, linked in series or in parallel to produce the wanted output The essential equation of the semiconductor theory, which arbitrarily define simple equivalent circuit of the photovoltaic cell model.
The produced current of PV as shown,

$$I = I_{pv,cell} - I_{0,cell}\left[exp\left(\frac{qV}{\alpha KT}\right) - 1\right] \quad (2.1)$$

The simple PV cell does not express the I–V curve of an actual PV array. Cells linked in parallel increase the current while cells linked in series produce higher output voltages. Practical arrays are formed of some linked PV cells and the detection of the property of the effect of the PV array requires the composition of combined parameters to the fundamental equation.

$$I = I_{PV} - I_0\left[exp\left(\frac{V+R_S I}{V_t \alpha}\right) - 1\right] - 1\frac{V+R_S I}{R_P} \quad (2.2)$$

We assume I_{sc} and I_{PV} are ordinarily used in the PV device modeling as in working designs the parallel resistance is high but series resistance is low.

The diode saturation current is presented by:

$$I_0 = \frac{I_{SC,n} + K_I \Delta_T}{exp\left(\frac{V_{OC,n} + K_V \Delta_T}{\alpha V_t}\right) - 1} \quad (2.3)$$

From the equation, the model is simplified and the model error is equal to zero near the open-circuit voltages, and as the results, at other regions of the I–V plot:

$$I_{PV} = (I_{PV,n} + K_{I \, \Delta_T}) \frac{G}{G_n} \qquad (2.4)$$

The R_S and R_P the relationship is an unknown of (2.2) may be calculated by setting $p_{max,m} = p_{max,e}$ and solving the fulfillment equation for R_S, as given:

$$P_{max,m} = V_{mp} \left\{ \begin{array}{c} I_{PV} - I_0 \left[exp\left(\frac{q}{KT} \frac{V_{mp} + R_S \, I_{mp}}{\alpha N_S} \right) - 1 \right] \\ - \frac{V_{mp} + R_S \, I_{mp}}{R_P} \end{array} \right\} = P_{max,e} \qquad (2.5)$$

$$R_P = \frac{V_{mp} + I_{mp} \, R_S}{\left\{ V_{mp} \, I_{PV} - V_{mp} I_0 \, exp\left[\frac{(V_{mp} + R_S \, I_{mp})}{N_S \alpha} \frac{q}{KT} \right] + V_{mp} I_0 - P_{max,e} \right\}} \qquad (2.6)$$

The means of equation 2.6 that for any value of R_P there will be a value of R_S that makes the mathematical I–V curve cross the experimental (I_{mp}, V_{mp},) point.

The aim is to find the value of R_P and R_S for the best model solution.

$$I_{PV,n} = \frac{R_P + R_S}{R_P} I_{SC,n} \qquad (2.7)$$

The initial conditions can be set as:

$$R_S = 0, \quad R_{P,min} = \frac{V_{mp}}{I_{sc,n} - I_{mp}} - \frac{V_{oc,n} - V_{mp}}{I_{mp}} \qquad (2.8)$$

From equation (2.8), the minimum value of R_P Is given by the relationship between the maximum-power points and the short circuit.

3. THE CONTROL PROGRAM OF GRID INTEGRATED PV SYSTEM

The control approach of Grid-Integrated PV, MPPT theory is applied. The boost converter increases DC voltage from 273.5 V to 500V. This component utilizes an MPPT system, which automatically changes the duty cycle to produce the necessary voltage to obtain maximum power. In this paper, the FLC controller is good control, a simulation model of PV is introduced giving an obvious view of the proper control PI, and the performance of any actual system with change time during the day can be used to investigate the performance of the PV generation system. The control is realized and examined in Matlab/Simulink program Fig. 3.1 grid integrated PV farm.
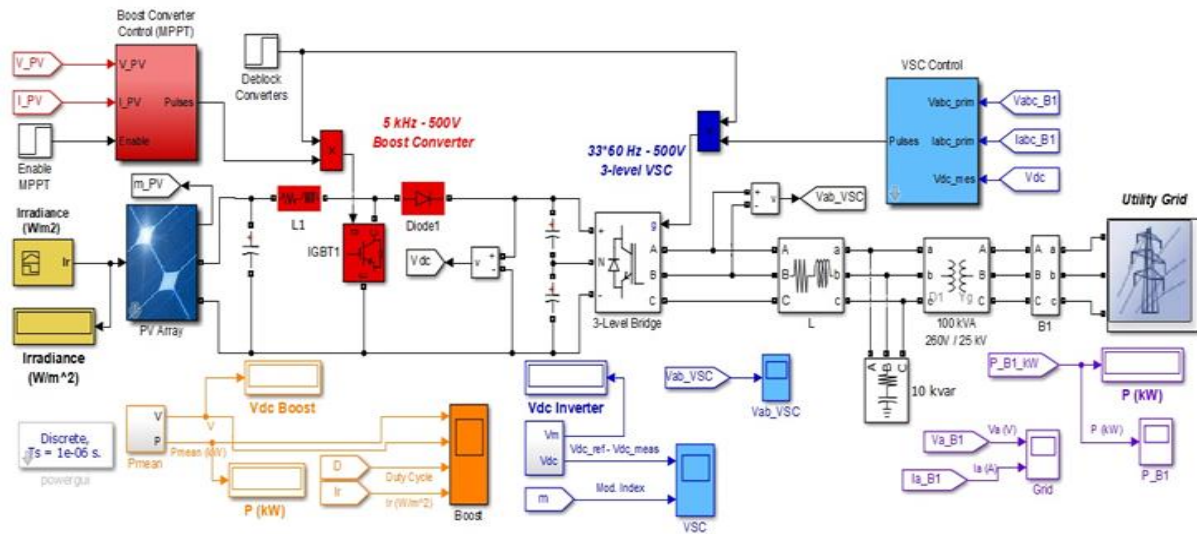

Fig. 3.1 Grid-Connected PV Farm

The algorithm framework that tests similarity enter amounts in Conditions of reasonable changeable that use on persistent values between (0,1) in dissimilarity to standard or digital logic, that works on detached values of as (1 or 0). A fuzzy logic controller can work to control the non-linearity and to do strongly than any other controller.

The FLC work in the following stages: [fuzzification, membership, functions, rule base, defuzzification] to control the system and get good results. The fuzzy logic controller inputs are two values one is the error and the second are the change in error, from this the value output is the duty cycle. The editor is shown in the Fig. 3.2 Grid converter fuzzy logic controller system, Fig. 3.3 Input variable "Error", Fig. 3.4 Input variable "Change of error", and Fig. 3.5 Output variable "Output".
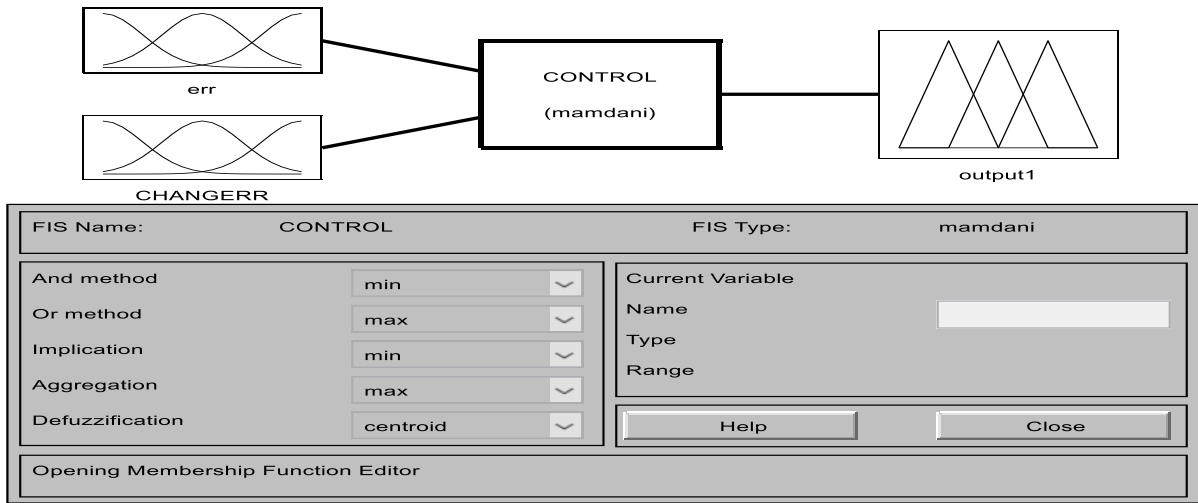
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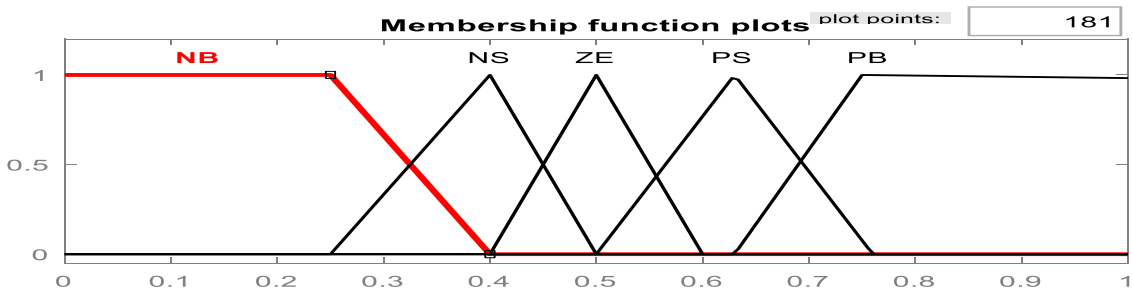**Fig. 3.2 The Grid Converter Fuzzy Logic Controller System**

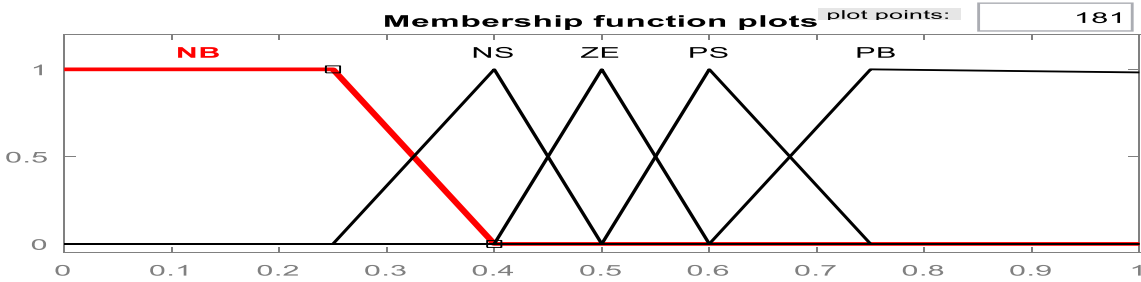**Fig. 3.3 The Input variable "Error"**

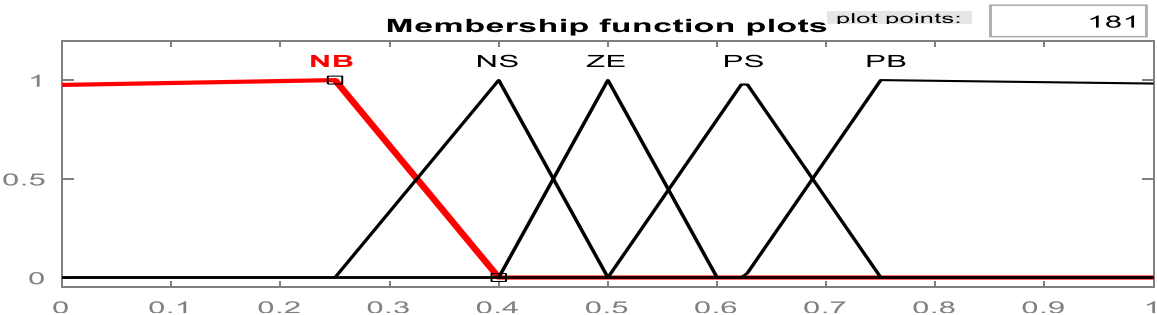**Fig. 3.4 The Membership function of "Change of error**

Fig. 3.5 The Output variable "Output"

3.1 MPPT Control Algorithm

The maximum power point tracking algorithms are desired because PV arrays have a non-linear voltage-current characteristic with a single point where the power produced is maximum. This point relies on the temperature of the board and on the irradiance time. Both terms vary during the day and are also unlike relying on the time of the year. Moreover, irradiation varies fast due to varying climatic phases such as cloudy intervals. It is important to follow the MPP exactly under all reasonable circumstances therefore that the supreme possible power is continuously achieved.

MPPT by incremental conductance method + Integral regulator MPP is obtained when:

$$C(s) = K_P + \frac{K_I}{s} \tag{3.1}$$

$$d(V * I)/dV = I + V * dI/dV = 0 \tag{3.2}$$

$$dI/dV = -I/V \tag{3.3}$$

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The FLC controller minimizes the error:

$$(dI/dV + I/V) \qquad (3.4)$$

3.2 Fuzzy Logic Controller System (FLCS)

The Fuzzy Logic Control system, Inverter in the integration of PV into the utility grid. The effort starts to study the utilization of the fuzzy logic controller design in the renewable energy system, particularly PV, micro-grid. So, the fuzzy logic controller designs are greatly utilized in the last few years for renewable energy systems, for PV, the maximum power point tracking in solar (MPPT) of PV power systems, optimization between different criteria. The study shows that fuzzy logic controller designs give pragmatic estimates.

The FLC is added between rectifier, PV produces, also use in the boost converter. The fuzzy logic controller is utilized to control regular current and voltage Over the framework. The produce of the fuzzy logic controller is work in the system which is provided to the gate pulse of design in the hybrid renewable energy system that is applied to the boost converter.

4. SIMULATION RESULTS

The fuzzy logic controller of the integration of the PV system into a grid will be created and examined by using MATLAB/SIMULINK utilizing a block set of the power systems. The generating energy from the PV system framework can be changed according to the various values of heavily on weather conditions in PV. The output from the inverter system DC voltage is suitable and the voltage stabilizes after short and the current is regular and suitable by using the fuzzy logic controller of integration of PV system into a grid that has been created and examined utilizing MATLAB/ SIMULINK using the power systems block set. The selected simulation parameters of the solar equivalent circuit and MPPT are given in Table 4.1.

Table-4.1 Parameters of the System

Parameter	Value	Parameter	Value
No. of cell	96	R_p	999.51
V_{oc}	64	R_l	5 Ω
I_{sc}	5.96	L	5 mH
V_{mp}	54.7	C_3	1200 MF
I_{mp}	5.58	K_p	2
R	0.038	K_i	10

A MATLAB/SIMULINK model for the 500 KW grid integrated PV control was summarised and described in this work. This model is depending on the essential circuit of a solar PV cell considering the consequence of various parameters such as solar radiation.
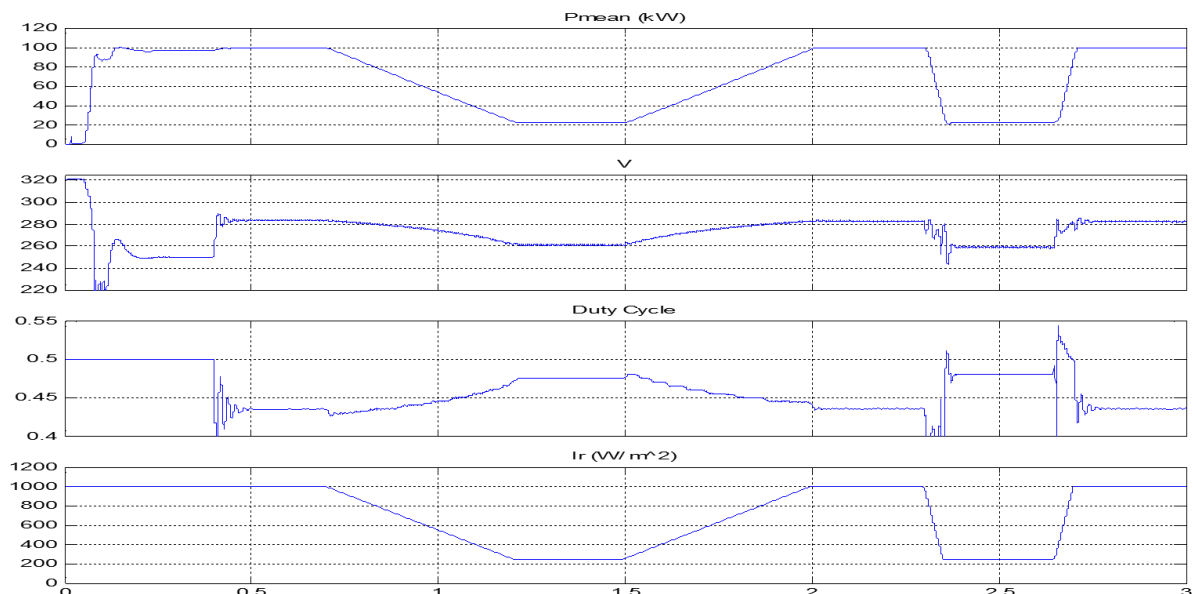

Fig. 4.1 Response of Altering Irradiance Corresponding MPPT Algorithm Output Voltage, Output Power, and Duty Cycle

The PV integration is connected to the boost DC/DC converter and the controller system is based on the maximum power point tracking (MPPT) with PI controller helps PV to ensure the maximum power in case of fluctuation in the weather, and then integrated into the AC utility grid by DC/AC inverter. Through the simulation results, it presented that the system tracks maximum power when the irradiance stays constant.

The electrical circuit is discredited at 1μs sample time, whereas the sample time used for the control systems is 100μs the simulation result of changing irradiance corresponding MPPT algorithm for PV Systems using a

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fuzzy logic controller with Boost DC/DC Converter is shown in figure 1. From this figure, it is observed that the performance of the PV grid under different irradiance variations. It can be indicated that this kind of MPPT controller follows maximum power only when irradiance remains fixed.

CONCLUSION

The paper presents a fuzzy logic-based control model for an integrated PV system and the utility grid. This fuzzy logic-based model is based on the basic circuit of the PV system and integrated into the grid showing the effects of regulating the grid-side converter control system. The system behavior and performance of the developed system in Matlab are studied. The controller system is based on a grid-side converter control system with a fuzzy logic-based controller that ensures the power regulation in case of fluctuating weather conditions, which is then integrated into the AC utility grid by DC/AC inverter. The results are relevant and show a fair degree of accuracy.

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