A New Fuzzy based INC-MPPT Algorithm for Constant Power Generation in PV Systems

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Abstract**—**Nowadays, many solar photovoltaics (PV) are installed in the power grid. Maximum Power Point Tracking (MPPT) method is used to maximize the power in solar PV. However, the power maximum in PV can cause overvoltage in the power grid. Therefore, this project discusses a modified Incremental Conductance (IC) MPPT algorithm for Constant Power Generation (CPG) under fluctuated solar irradiation. This method is combining MPPT with power control adjustment for limiting the maximum feed-in power of solar PV systems. The proposed control strategy will be able to regulate two conditions of solar PV operation, first for MPP operation on under reference power and second for CPG operation on upper reference power. Simulation results of proposed control method have verified for various reference power and irradiance and show high accuracy, stable and fast response.

Keywords—Photovoltaic; Modified Maximum Power Point Tracking; Constant Power Generation

I. INTRODUCTION

The renewable energy sources especially solar Photovoltaic (PV) systems have increased over the world wide. But, The generation of power using solar PV modules is always fluctuate depending on environmental conditions especially solar irradiation and environment temperature. Hence, implementation of solar PV always included with MPPT controller to reach maximum energy of solar PV and transfer it to the load [1]. Installing solar PV module to a load without applying an MPPT controller, the energy delivered from solar PV module is determined by the load resistance, so there is no guarantee to get maximum energy from the PV module [2].

According to the literature review, many MPPT methods have been developed to operate and force solar PV on maximum power point (MPP) for generating electrical energy [2-3]. All these tracking algorithms were developed aimed to get shortest tracking time or smallest steady state oscillations.

Perturbation and observation (P&O) algorithms [4] is particularly popular approach because it is simple to implement [5]. However, P&O has low accuracy because operation of MPPT is oscillated around MPP. The incremental conductance (IC) algorithms is proposed to improve the accuracy of MPPT because operation of MPPT does not oscillate around of MPP [6], [7], [8]. However, IC is not used to avoid of overvoltage under MPPT condition.

In fact, MPPT algorithm is worked together with a DC-DC converter whose duty cycle is always changed according to MPPT algorithm to force solar PV module operated always on MPP for whatever load resistance value. But, there are the fluctuate irradiance and non-constant load, which they are has possibility of seriously failure for over voltage or over current during duty cycle adjustment. Current-voltage characteristics and output power of photovoltaic (PV) strings vary with changes of solar irradiance, temperature and aging. Accordingly, maximum power point tracking (MPPT) techniques are applied in most
of applications in order to maximize the extracted power from a given PV system and increase the overall power conversion efficiency [9]. Several MPPT algorithms, varying in approach and complexity, have been introduced in the literature [10]-[18].

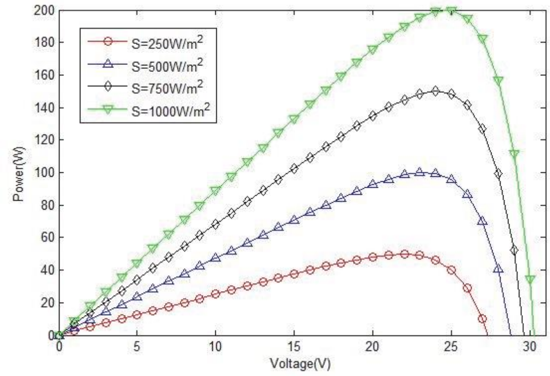
Each method has various advantages and disadvantages in different aspects like computational efficiency, speed of tracking the maximum power point, operation under partial shading and power oscillations during steady-state. Among all MPPT algorithms, perturb and observe (P&O) [19]–[21] and incremental conductance (INC) [22], [23] algorithms are the most commonly used. It is shown in [24], [25] that the tracking performance of these two algorithms is similar under both static and dynamic conditions. The focus of most of the research studies in the literature is on the extraction of maximum power from PV panels, however, there are several cases in which the control of the PV panel output active power to a certain power reference is necessary.

The active power control of the PV panel is referred as constant power generation (CPG) in this study. One of these cases is the adaptation of PVPPs with new grid code regulations in which a constant power injection to the grid is requested. The grid codes aim to avoid the adverse effects of the high penetration of installed PVPPs in the power system, like overloading the power grid [26]. Another case is their operation during voltage sags with the requirement of simultaneous injection of active and reactive power to the grid with the aim of enhancing the voltage of the point of common coupling (PCC).

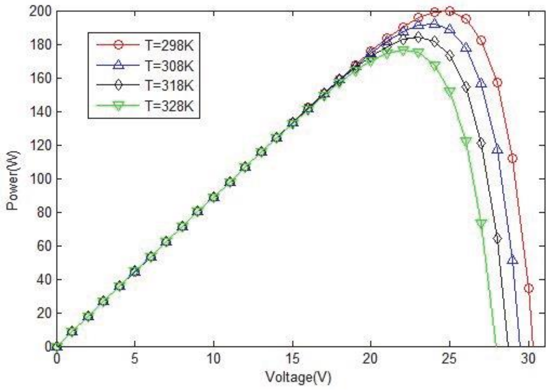
By assuming that the irradiance is constant during the short duration of voltage sags, the extracted power from PV modules should be limited to a certain value in order to satisfy the inverter current limitations [27]. Therefore, a general and flexible algorithm that achieves CPG with fast dynamic response and low power oscillation during steady state is essential for all different topologies of PVPPs.

II. CHARACTERISTICS OF PV MODULE AND MPPT

The solar PV module operation depends on the load resistance and is greatly influenced by solar radiation and environment temperature. In the fig. 1(a) & 1(b), demonstrate that irradiance increase then the power of PV also increasing. Moreover, temperature increase then the power of PV will decreasing.



(a)Under Different Solar Irradiances



(b)Under Different Temperatures

Fig. 1. Characteristics of solar PV output power influenced by irradiance and temperature.

In the case of MPPT, solar PV are worked together with a DC-DC converter whose duty cycle is always changed to reach MPP operation according to implemented MPPT algorithm.

The general block diagram of an MPPT is depicted in Fig. 2, from this figure it, MPPT algorithm need a sensor of voltage and current, both sensors are installed at the DC-DC converter input side and then a reference voltage or PWM duty cycle will be adjusted by its implemented MPPT algorithm. To reach MPP condition, MPPT controller is always changing duty cycle according

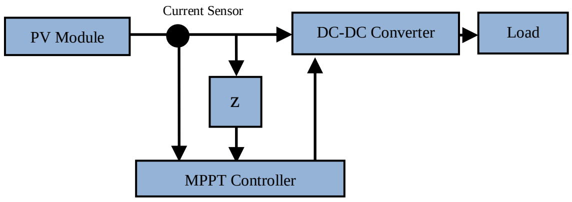


Fig. 2. Block diagram of a MPPT

to MPPT algorithm. This action is high possible causes the fluctuating voltage on DC-DC Converter output, especially for condition non-matching load resistance.

To avoid and protect loads from failure of over voltage can be solve by adjusting solar PV feed-in power on DC Busses. These techniques can be performed by two ways voltage limitation and power limitation or constant power generation (CPG). Both method are modifying MPPT algorithm. The CPG operation have two possible position, on right of MPP or left of MPP. Each method has own specific advantage and disadvantage [10]. Fig. 3. illustrated operation of solar PV on MPPT and CPG operation.

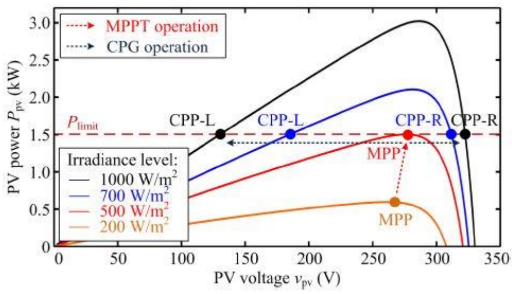


Fig. 3. Operation of solar PV on MPPT and CPG operation [8].

III. PROROPOSED TECHNIQUE

The block diagram for proposed control method MPPT and CPG is depicted in Fig. 6. The flowchart of tracking algorithm and its modified is depicted Fig. 4. The proposed control has two operation mode, the first is MPPT operation, and this MPPT operation is operated while solar PV output power production under *Pref*. The second operation mode is the CPG operation. This mode is operated while available solar PV output power production over *Pref*.

In the CPG operation mode, solar PV does not force operate on MPP condition, but according to reference power limit, so the feed-in power is less than the maximum value, as the result of this operation, the DC Bus is saved from overvoltage failure.

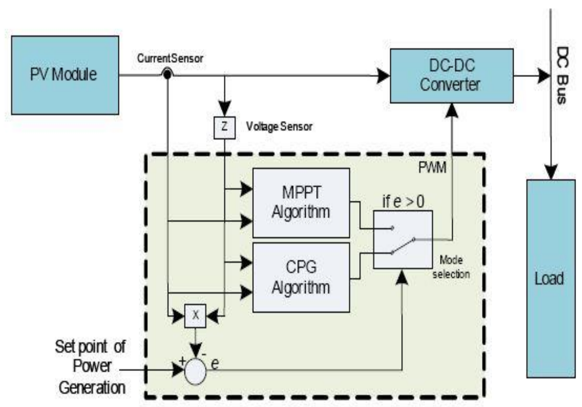


Fig. 4. Block diagram for proposed control method MPPT and CPG.

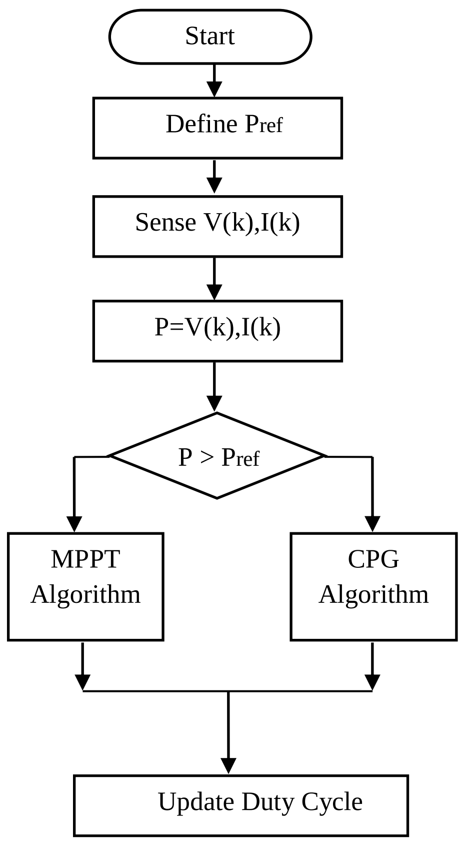


Fig. 5. Flowchart for proposed MPPT and CPG algorithm

In this paper observed MPPT technique IC algorithms for MPPT operation. And also observed modified IC algorithms for CGP operation. The main consideration of this method is the performance in terms of the speed to reach system converges on both for MPPT operation and CPG operation, and the low ripple after reach steady state condition. For clearly on how MPPT and CPG are implemented, flowchart for algorithm are shown in Fig. 6.

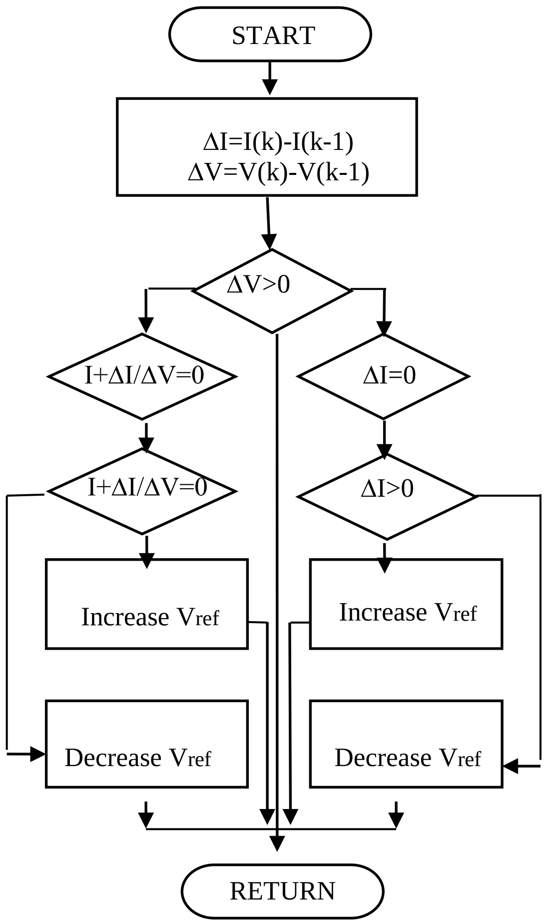


Fig. 6. Block diagram of modified IC MPPT algorithm proposed for CPG.

The proposed modified IC MPPT algorithm shown on Fig. 9., basically both modified algorithm almost same with original IC MPPT algorithm, but in the modified algorithm the technique is applied on left of MPP.

IV. SIMULATION RESULTS

To simulate the performance of the proposed Fuzzy based CPG algorithm PV module is characterized by a rated current of 4.91A. Thus, the total output voltage of the PV array is 23V to 30V and output current is 1.2Ato 9.6A.

The results illustrated in fig. 8 and fig. 9 Prior to t =0.5s, the PVPP operates at MPPT and the maximum available power of the PV string extracted is 50kW by INC-CPG method, where as the proposed Fuzzy based CPG method extracts 51.5 kW.

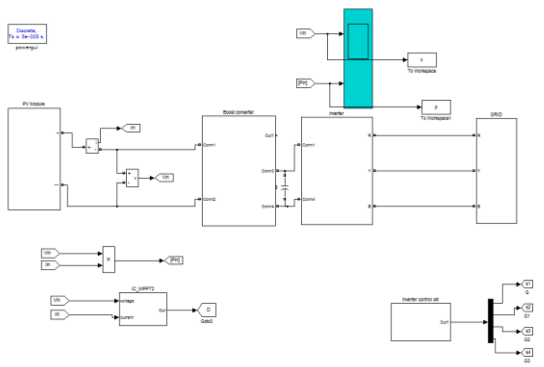


Fig. 7.Complete Matlab/Simulink Model of the Proposed Fuzzy based CPG System.

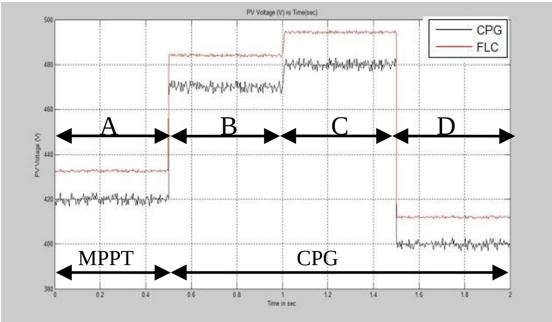


Fig.8.Output voltage of INC-CPG and Fuzzy based CPG PV Systems

	Power(kW)			
	A	B	C	D
INC-CPG	49.2	37.5	31.3	4.6
Fuzzy-CPG	51.5	39.3	33.7	4.2

Table 1
Comparison table for Output powers in INC-CPG and Fuzzy based CPG PV Systems

At t = 0.5s, the operation mode is change to CPG from the PVPP central controller with Pref = 37 kW and therefore, the proposed CPG algorithm quickly regulates the PV string power to the required power reference on left side of MPP.

The power reference is decreased to Pref = 12 kW at t = 1s. Consequently, the proposed algorithm increases/decreases the voltage reference in the right-/left-side of MPP to adjust the PV panel power with its reference value. Due to the step reduction of the irradiance at t = 1.5 s, the voltage may go beyond the open circuit voltage of the PV panel under such irradiation, which is 486 V respectively.

The proposed algorithm decreases the voltage reference under such condition and consequently brings the operation point inside the P-V curve range of the PV panel. Because the maximum available power of the PV string under this condition is smaller than Pref , the algorithm adjusts Vpv, to Vmpp during this period.

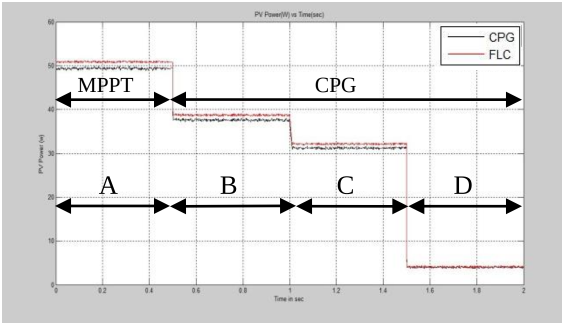


Fig.9.Output power of INC-CPG and Fuzzy based CPG PV Systems

	Voltage(V)			
	A	B	C	D
INC-CPG	420	450	480	400
Fuzzy-CPG	432	485	495	412

Table 2
Comparison table for Output voltages of INC-CPG and Fuzzy based CPG PV Systems

Simulation results and comparison tables demonstrate the generality and enhanced power and voltage levels of the proposed CPG algorithm with the flexibility to move the operation point of the PV panel to the right- or left-side of MPP. Furthermore the robustness of the proposed algorithm in regulating the PV panel power under step change of irradiance and power reference is demonstrated under various operation conditions.

V.CONCLUSION

Detailed implementation of the proposed Fuzzy based CPG algorithm has been presented and its flexibility and effectiveness has been demonstrated on 50-kVA PVPP simulation setup under various irradiance and power reference profiles. The PVPP obtains CPG capability under all of the presented severe operating conditions. Also, it is shown that if the target power reference is larger than the maximum available power of the PVPP, the proposed algorithm operates at maximum power point.

Furthermore, the robustness of the proposed algorithm for regulating the PVPP power while its operation point goes beyond the open-circuit voltage of the PV panel due to sudden decrease of irradiance is demonstrated with results for both PVPP topologies. The results demonstrate flexibility and generality of the proposed algorithm as an additional function for existing MPPT algorithms in grid-connected PVPP.

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