Enhanced MPPT Performance of PV systems using FOPID Controller

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Abstract: To maximize the amount of energy produced by PV modules, the Maximum Power Point Tracking (MPPT) control approach is still being developed. The three basic categories of perturbing current, perturbing duty cycle, & perturbing voltage may be used to categories several MPPT control techniques. This study first analyses the output properties of a mathematical model of photovoltaic modules under various lighting scenarios, then it suggests a FOPID controller. The first element assures the maximum power point stability and the speed of the rising the stage, while the second part guarantees the consistency of the Boost converter's output voltage and output current. Simulation findings are contrasted with the traditional P&O technique and the two-stage adjustable step-size disturbance duty cycle using MATLAB/Simulink to develop various components of the system design. The outcomes of the simulation demonstrate that the suggested algorithm is able to attain a good capacity of rapid ascent, security, or responsiveness to environmental change. The results demonstrate the compatibility with the simulated results from the verification test on the experimental system.

Keywords: ***Electric Vehicle, Photovoltaic cell, FOPID, MPPT.***

I.INTRODUCTION

Currently, there are numerous techniques for control for MPPT. They can be categorized into three groups based on perturbing techniques: perturbing current, perturbing duty cycle, or perturbing voltage. The method of disrupting current has the drawbacks of having a big maximum power point oscillation and poor control

accuracy. In theoretical research or engineering applications, it is uncommon. The perturbing duty ratio approach, also known as the perturbing observation technique, is currently being researched [1-2]. However, there is power oscillation close to the maximum power point. The tracking speed and oscillation amplitude are determined by the perturbing step. The technique of perturbing voltage, usually referred to as "hill climbing," is frequently applied in engineering. The DC-DC converter needs to be included to this method's closed-loop control, which is a frequent feature. But perturbing voltage outperforms the first two strategies in terms of control effect or control precision [3].

Rest of the work is arranged as follows. In section II describes the model and characteristics of PV. Section III explained the proposed FOPID controller parameters. Section IV gives the literature Survey. Section V contains the problem formulation and objectives. Section VI contains the results and discussion part. Finally, section VII ends the paper with conclusion followed by references.

II. MODEL AND CHARACTERISTICS OF PHOTOVOLTAIC MODULES

The mathematical equation of photovoltaic module is

$$I_{pv} = n_p I_L - n_p I_0 \left[\exp\left(\frac{q(V_{pv} + I_{pv} R_s)}{AKTn_s}\right) - 1 \right] - \frac{V_{pv} + I_{pv} R_s}{R_{sh}}$$

The controlled current source reverse-parallel diode and resistance are used in the traditional single-diode physical model of photovoltaic cells to represent the photogenerated current or the reverse current [4]. Fig. 1 depicts the corresponding circuit for it.

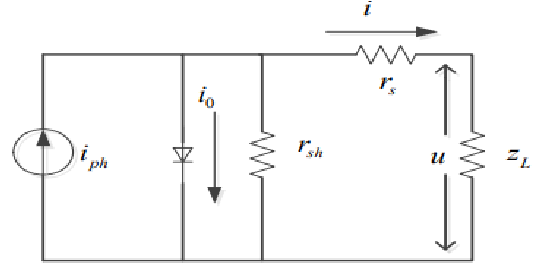

Fig.1 physical model of photovoltaic cell [4]

The two-point approach and its enhanced approach are frequently used in engineering applications to reduce problems to some extent [5]. In other words, the module's shunt resistance is initially disregarded, and the photogenerated current is considered to be equal to the short-circuit current because the series resistance is significantly lower than the overall forward-conducting resistance of the diode. Then, to construct a rough model, the voltage and current in the open-circuit state and the maximum power point state are swapped into the equation. [6] is the model equation.

$$I_{pv} = I_{sc}\left\{1 - C_1\left[\exp\left(\frac{V_{pv} - dv}{C_2 V_{oc}}\right) - 1\right]\right\} + di$$

III. FOPID CONTROLLER

The various definitions and approximations for fractional order controllers include Rieman-Liouville, Grunwald-Letnikov, the Caputo expressions, Carlson approximation, Matsuda estimation, the continuous fraction expansion (CFE) technique. The fundamental transfer function of the FOPID controller is, as seen in equation (1),

$$G(s) = K_P + \frac{K_i}{s^{\alpha}} + K_d s^{\beta}$$

where a,fJ are the positive fractional orders and Kp, K1 and Kn are the proportionate gains. The use of S forces is extremely challenging since the differentiator or integration of the fractional order have infinite dimensions. Therefore, estimating the fractional powers is crucial. The most used approximate method for fractional order controllers is the oustaloup approximation, and so this article also makes use of this method [7]. It must first be modelled as a differentiator that use the Oustaloup approximation approach before being split by s to produce a fractional order integrator. The general expression for the approximation of the Oustaloup filter is

$$s^{\alpha} = K\prod_{k=-N}^{N}\frac{s+\omega'}{s+\omega}$$

$$\omega' = \omega_b\omega_u^{(2k-1-\alpha)/N},\ \omega = \omega_b\omega_u^{(2k-1+\alpha)/N}$$

$$K = \omega_h^{\alpha},\ \omega_b = 10^{-\alpha}$$

IV.LITERATURE SURVEY

Singh et al., (2020) a solar PV (Photovoltaic) array, a battery energy storage (BES), a diesel generator (DG) set and grid based EV charging station (CS) is utilized to provide the incessant charging in islanded, grid connected and DG set connected modes. The charging station is primarily designed to use the solar photovoltaic PV array and a BES to charge the electric vehicle (EV) battery. However, in case of exhausted storage battery and unavailable solar PV array generation, the charging station intelligently takes power from the grid or DG (Diesel Generator) set. However, the power from DG set is drawn in a manner that, it always operates at 80-85% loading to achieve maximum fuel efficiency under all loading conditions. Moreover, the PCC (Point of Common Coupling) voltage is synchronized to the grid/ generator voltage to obtain the ceaseless charging. The charging station also performs the vehicle to grid active/reactive power transfer, vehicle to home and vehicle to vehicle power transfer for increasing the operational efficiency of the charging station.

Das et al., (2016) A BDDDC is a dc to dc converter where the power can flows is in both the directions as supply end to load end and also load end to supply end. It has two modes of operation, buck mode & boost mode. Utilize PI and PID controller for triggering the IGBTs of DC to DC converter. The findings outcomes give that for both 24V and 48V input voltage the conventional boost converter efficiency is 55 % and for proposed boost converter the efficiency is 74% .

Sadigh et al., (2018) a FOPID controller for a UAV is assumed. Also, a detailed design and description of the UAV is provided or discussed. Focused on the results, the behavior of the device by utilizing FOPID is best than PID. In addition, PSO is used for optimization of the suggested FOPID. The dynamic equations of the UAV are elaborated as well as then, a FOPID controller is modelled for the device. The efficacy of the paper is shown depend on the simulation on MATLAB.

Mary Ann George et al., (2020) provides a fractional analog system for realizing a fractional- order PID (FOPID) controller to use an Extra-X second-generation current conveyor (EX-CCII). The FOPID controller is intended for an electric vehicle speed control application that takes into account the electric vehicle's model. The Astrom-Hagglund (AH) tuning method is used to develop the controller variables. The Neider-Mead (NM) optimization method is used to reduce the order of integrator as well as differentiator phases. The circuit is built with a single active element as well as an RC network. The LTspice simulator for the TSMC 0.35 m

CMOS method is used to analyze the controller design variables .

Marzaki et al., (2015) presents a comparison of FOPID and PID controllers for controlling steam temperature in the SMISD plant. The simulation as well as real-time implementation results shows that the FOPID has stronger controller response, particularly in terms of rise or settling time in a noiseless environment. When the material is applied to irregular high frequency noise, the FOPID controller has a massive amount of MSE and a poor response in maintaining its steady state response. More work is aimed to enhance generates high.

Ke Guo et al.,(2020) The MPPT output on the PV process is influenced with the suggested IGWO method under static and dynamic PSCs and contrasted with other typical perturbation and observation (P&O), particle swarm optimization (PSO), artificial bee colony (ABC), salp swarm algorithm adapt inertia weight (WSSA), grey wolf optimizer salp swarm automated system (SSA- GWO). The efficiency and stability of the suggested control strategy, particularly speed tracking under PSCs, are confirmed. Results show that in most cases, the BFBIC configuration with the suggested IGWO methodology outclasses other architectures, particularly taking only 0.24s tracking time and achieving 98.54 percent efficient under the most extreme PSCs.

Liu et al.,(2019) A Double Closed Loop MPPT Control Strategy Based on Increased Hill Climbing is suggested in accordance with the engineering mathematical model of the solar module and based on the MPPT control system of the Boost circuit. MATLAB is used to model and analyse the proposed method. The simulation findings demonstrate that the MPPT control strategy with stage-by-stage variable step size may guarantee MPPT's speed and stability, i.e., its capacity to achieve its maximum power point as quickly as feasible and to minimise oscillation around it. By employing the double closed-loop control method of disturbance voltage, the output voltage of the module may be made more stable. It has the capacity to quickly resume stable operation when the external environment shifts.

Zhu et al.,(2018) A modified hill climbing method is suggested to guarantee that the photovoltaic (PV) system can still output maximum power under changing environmental conditions. By introducing boundary constraints, the method employs a variable step-size strategy to reduce steady-state oscillations and keep the operating point from straying from the maximum power point. The suggested algorithm is compared with the traditional and adaptive hill climbing method under the environmental conditions of irradiance step change and progressive change in order to demonstrate its efficacy. Simulation findings demonstrate that the suggested algorithm may achieve a steady-state tracking accuracy of 99.8% while increasing the dynamic response speed of the PV system by 75% under variable irradiance.

V.PROPOSED WORK

- PROBLEM FORMULATION

MPPT techniques are used widely used in the field of solar based application. PV arrays are responsible for giving the required output and achieving the solar energy which is converted into electrical energy and is used for different purposes. Charging is one of the most imperative tasks that have become popular and researchers are also doing research in this field to charge the appliances effective. To this end, different technologies have been used in which PV arrays are used with different MPPT techniques. It is very important to choose accurate technique to enhance the work. In a recent work, Authors have used Perturb & Observe MPPT technique for PV array to charge the battery using solar energy. The detailed study of the approach showed that it gives better output but hill-climbing has some limitations which should be taken into consideration. Following are the shortcomings of using hill-climbing in solar based charging of batteries:

1. When hill-climbing is applied, it takes the decisions faster when the step size of error is also increased which in turn reduced the efficacy of MPPT.
2. Secondly, it leads to change the direction errors under varying rapid atmospheric changes.
3. Moreover it is no capable of determining actual location of MPP.

Thus, it is required to over the problem by upgrading the model.

- Objectives

1. To replace hill climbing method with the FOPID controller to improve MPPT operation
2. To perform comparaive analysis of proposed and existing model to validate the performnace.

VI.RESULTS

One of the most important forms of renewable energy in the future will be solar energy. PV system generates its greatest output power, make the usage of PV difficult in many climatic circumstances around the world & its nonlinear current-voltage (I-V) features, which result in a distinct Maximum Power Point (MPP) on its power-voltage (P-V) curve. In order to tackle the issue that arises when a PV module is coupled to a load and the operating point is not exactly at the MPP and MPPT methods are used in PV systems to extract the array's maximum output power. During in simulation utilizing the MATLAB/Simulink software package, the suggested FOPID controller suggested to improve performance. In this section, results and discussion are shown in two sections, 1) Output of solar PV array, 2) Output of DCDC converter . The proposed method of FOPID controller to improve a MPPT of the solar photovoltaic array for charging off-board electric vehicles using two sensors has been tested and simulated using MATLAB Simulink and steady charging current under the specified limit was maintained by proposed strategy during the simulation of the system.

Photovoltaic's (PV) is the conversion of light into electricity using semiconducting materials that exhibit the photovoltaic effect, a phenomenon studied in physics, photochemistry, and electrochemistry. The photovoltaic effect is commercially used for electricity generation and as photo sensors.

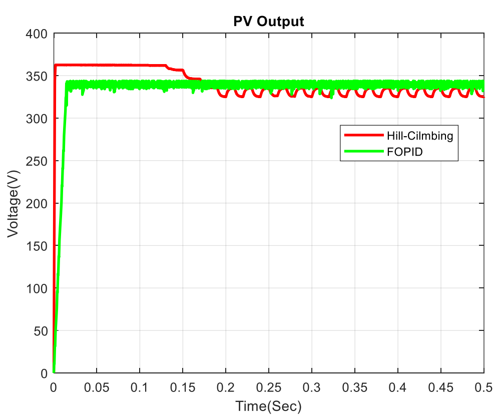

Figure 2: PV output for voltage v/s time

The findings and conclusions are presented in this section in two parts: 1) Output of solar PV array, and 2) Output of DCDC converter. MATLAB has been used to test & simulate the suggested FOPID controller technique to enhance an MPPT of the solar photovoltaic array for charging off-board electric cars. During the system's simulation, the recommended method kept the Simulink or stable charging current under the designated limit.

Utilizing semiconducting materials that show the photovoltaic effect, a phenomenon researched in physics, photochemistry, and electrochemistry, photovoltaic's (PV) converts light into electricity. Commercial applications of the photovoltaic effect include making photo sensors and powering solar panels.

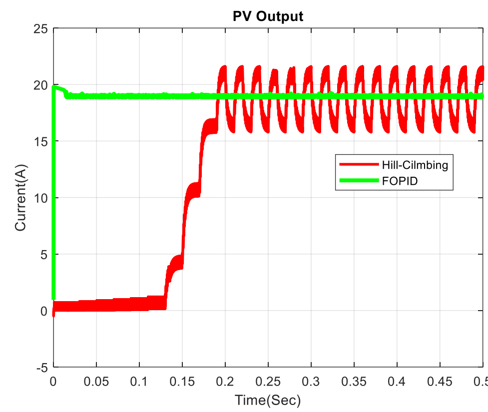

Figure 3: PV output for Current v/s time

A photovoltaic (PV) solar cell's power output is determined as the sum of its voltage & current. The short circuit current is the greatest amount of current that a PV cell is capable of producing.

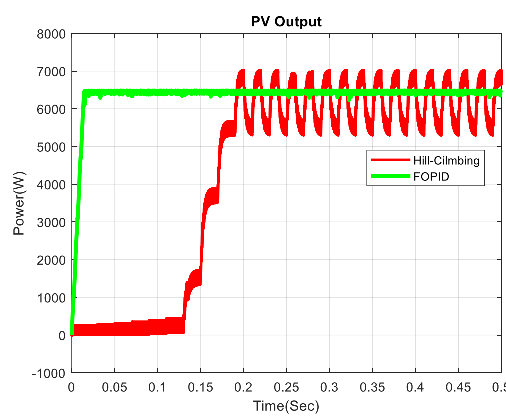

Figure 4: PV output for Power v/s time

A circuit known as a DC-DC boost converter increases a low, fluctuating DC input voltage to a higher, stable DC output voltage. To increase the voltage across the load, a switch, an inductor, a diode, and a capacitor are used. The input voltage, load current or switching frequency all affect output voltage variation. Voltage feedback is used by the boost converter to maintain a steady output voltage.

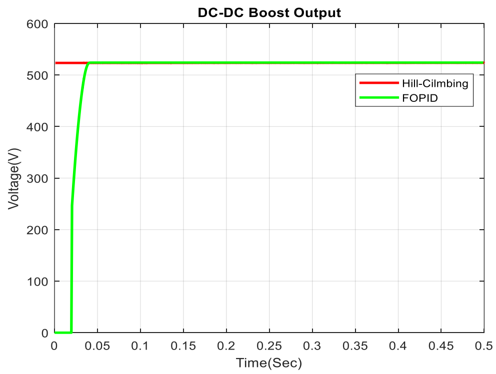

Figure 5:DC-DC Boost Output for Voltage

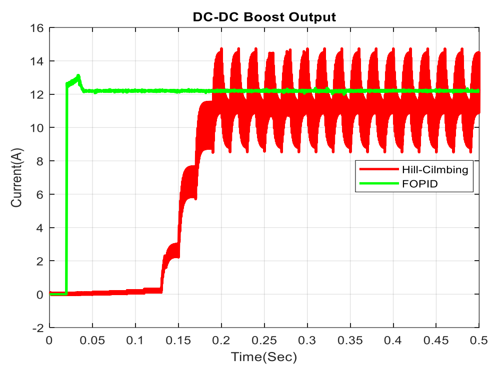

Figure 6: DC-DC Boost Output for Current

It is shown by figures 2 to 6 that the suggested solution, which uses a FOPID controller, performs better than previous approaches.

VII.CONCLUSION

The suggested controller is clearly tracking the MPP well despite changing atmospheric conditions. In order to generate reference voltage, a FOPID controller uses the algorithm known as P&O to calculate the reference power. Subsequent calculations drive the reference power, which is deducted from the generated output power. The FOPID controller receives the estimated error—the difference between the reference and output powers and uses it to control the inverter's switching. Additionally, the suggested controller is put to the test in various environmental conditions to confirm its efficacy. The results show that the FOPID controller performs better than other controllers in terms of convergence speed, settling time, and oscillations.

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