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Optimizing Power Ramp Capabilities of PV Systems using Fuzzy MPPT

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ABSTRACT

Maximal Power Point Tracking (MPPT) algorithms are generally sufficient for tracking the optimum power point of a solar or photo voltaic (PV) system. But when ramps occur in the PV systems, then only MPPT controllers are not sufficient and we need an improved controller to perform the task of ramp minimization. In this paper we propose a fuzzy based MPPT controller to control the ramp capabilities of a PV system, which is found to be superior to the normal MPPT based controller. The results and observations show that the proposed controller has 10% higher efficiency in ramp control when compared to standard MPPT controller, and thus it can be used in real time environments where there is a need to control the ramp capabilities to a large extent.

Keywords: *Fuzzy, power ramp, solar, PV, MPPT, PI*

1. Introduction

Lately, the overall limit of sustainable power source frameworks has become quickly so as to assuage the decaying ecological issues produced by petroleum products. Among various sustainable power sources, sunlight based vitality is a standout amongst the most encouraging assets for substantial scale power generation [1]. In any case, the key boundary against high PV entrance is the power yield fluctuation, which is for the most part brought about by cloud shading [2]– [4]. On account of an extensive framework associated PV framework, passing mists can bring about fluctuating force being consistently infused into the power network, prompting substantial power slope rates [5]. The uncontrolled PV infiltration may change the dispatch of utility controlling, and in this way cause an infringement in dispatch managing edges [6].

In little power frameworks, for example, islands, the discontinuous PV power can cause consonant contortion in current and voltage waveforms and even power outages [7]. Therefore, PRRC is presented as the guideline of PV yield control change rate. For example, Germany and Puerto Rico require a most extreme slope rate of 10% every moment of the appraised PV control [8]. There are three regular approaches to accomplish PRRC: (1) combination of ESS, (2) dynamic power abridgement by greatest power point following (MPPT) control, (3) ESS-MPPT cross breed framework. Figure 1 demonstrates the PRRC standard of utilizing ESS. The strong line is the progression change of PV control, which speaks to the most pessimistic scenario. The ESS can store the excess vitality from the PV, and release when the abrupt yield control decline happens. PRRC is accomplished along these lines [9], [10]. In any case, the additional ESS will expand the expense of the general PV frameworks, and the constrained battery's life will influence the lifetime of the PV frameworks [11]. PRRC can likewise be accomplished through dynamic power decrease by controlling the task point far from most extreme power point (MPP) (for example MPP to An as appeared in Figure 2). Despite the fact that there are control misfortunes amid the diminishing, incline rate can be controlled successfully. In [12]– [14], PRRC is worked at the increase side, where the PV control increments quickly. Be that as it may, for an abrupt drop on the power level, these traditional PRRC methodologies are not suitable, since no outer gadgets can be utilized to alleviate the power vacillations. In reality, as appeared in Figure 3, it is conceivable to direct dynamic power decrease at the power drop side, as long as the working time tc can be anticipated. Different guaging strategies have been grouped by the time skyline. Numerical climate expectation models and satellite models were tried for 6 hours to a couple of days estimating in [15]. NWP models have been observed to be more precise than satellite models after 6 h dependent on the root mean square mistake metric. Be that as it may, because of lacking of granularity and computational proficiency, NWP models may lose the preferred standpoint in momentary determining (30 minutes ahead) [16]. For transient guaging, the customary methodology is to acquire cloud movement vectors (CMV) with sky imagers, satellite information or ground-based sensors [17]. In [15], the rare satellite information update and exchange delays has been presented, which can make the information gathering and preparing progressively perplexing. Peng et al. [18] proposed an anticipating framework dependent on numerous all out sky imagers (TSIs), and around 26% improvement has been accomplished. Be that as it may, sun powered recognition in the sunlight based district, just as the deciding of could thickness is testing. Therefore, nearby ground-based sensors are beneficial for momentary sun based power anticipating. Various techniques have been proposed to acquire CMV from ground-based sensors. Hinkelman et al. [19] determined the cloud speed by dissecting the slack between most extreme cross correlation between two sensors, however the cloud bearing can't be resolved naturally. Baldwin and Collins built up a sensor guaging framework orchestrated in two concentric circles; however no point by point calculation to decide CMV was presented [20]. Bosch and Kleissl inferred the CMV by utilizing a triplet of sensors at discretionary positions; nonetheless, this technique can't decide the cloud shading impact on the prompt power yield [21].

The next section describes some recent approaches for ramp rate control, followed by the proposed fuzzy MPPT PI model for smoothing the solar output power. The paper concludes with the results for the system, followed by some comparative observations about the developed system.

2. Literature review

There are particular fundamental issues that rise up out of changes caused from sun controlled PV plant interconnected to the scattering system. The basic issue from fluctuating sun controlled PV yield is voltage instability and voltage flash. Higher incline ups or downs in the midst of instability are seen to be the noteworthy explanation behind voltage change at the reason for interconnection at system side. There is no worldwide standard on RR limit as, 90% of RRs are of humbler degree. In any case with the creating number of significant scale sun arranged PV plants it is imperative to display RR control limits. Neighborhood government or regulatory bodies in various countries are getting the chance to be aware of the negative impact of higher RR and have endorse to constrain stricter RR limit [21]. For instance Hawaiian electric association (HECO) proposes compelling the incline ups or downs from reasonable generators inside ± 2 MW each minute for endeavors under 50 MW. In Germany the structure executive had constrained 10% of assessed limit for incline ups and there are no imperatives for slope downs [21]. In any case any colossal slope rates impacts voltage instability and need to pursue any worldwide or close-by benchmarks overseen by the specific utility executives. IEC 60038 rules are commonly used in most of the countries where the transport voltage is 230/400 V and the low voltage may move up to ± 10% from apparent regard [37]. Despite it, the voltage change issues is tended to through IEEE 1547, IEEE 1547– 2003, IEEE 929 standards [38, 39]. Table 1 shows the passable voltage deviation for different countries when economical power source is interconnected to framework under customary power age circumstance [40]. Control of PV increase/down is essential to alleviate the negative impact on the more delicate system. There are a couple of systems used in the composition to create the PV smoothed yield control ($\bar{P}$ PV). With everything taken into account, the smoothing systems are arranged as (I) MA and exponential smoothing based methods, (ii) channel based procedures, and (iii) RR control estimations based strategies. The accompanying figure outlines the PV incline rate (RR) control procedures, Mama and exponential smoothing (EXS) are methods used to oblige the RR of yield control from daylight based PV plant. Regardless, MA is generally used for PV yield control smoothing application in light of its ease in utilization and less computational effort. In [22] a symmetrical MA is associated with control the RR from the PV generator. Lead-destructive battery accumulating is used to smooth the PV yield control inorder to control the PV yield control RR inside the purpose of imprisonment. A RR control strategy subject to MA is proposed for a PV plant in [23]. The EDLC acclimatizes or discharges to control the fast fluctuation from PV plant, empowering it to change its yield at a confined RR. The use of both MA and EXS procedures are destitute down in [41] to oblige the fluctuation conveyed from the sun arranged PV plant. EDLC is used to confine the change conveyed by the PV plant. It was confirmed by the makers of [41] that both MA and EXS were amazing in confining the differences from PV plant in any case, EXS utilizes diminished breaking point of EDLC than MA methodology The usage of perfect control channel (OCF) to mitigate the change issue of sun situated PV plant was proposed in [29]. The OCF is overhauled with gauge module and is differentiated and MA procedure. The results attest that the OCF channel utilizes diminished utmost of ES when differentiated and MA strategy. That is, for the 10 MW PV farm, MA utilizes 1.25 MW h on the other hand OCF channel utilizes ES of point of confinement 0.3 MW h in a manner of speaking. On further examination, it was found that the solidified use of OCF channel with dump weight can contain the fluctuation inside the embraced measurement with furthermore diminished ES limit. Use of extended Kalman channel and atom channel to smooth the PV yield control is found in [60]. Merged BESS and diesel generator is used to smooth the yield control change from a sun fueled PV plant. Through the joined errand the makers had the ability to achieve half improved movement in diesel generator by constraining the infection starts, backing and redesigns. In [61] 10 kW h module cream electric vehicle (PHEV) battery chargers are proposed as a possible response for 100 kW sun based PV plant's spasmodic issue. In this way the proposed facilitated PV-PHEV structure utilizes first solicitation high pass channel to make an appropriate reference to PHEV battery chargers. The proposed structure guarantees PV-cross section compromise with reduced RR and snappy EV battery task with high viability. A second solicitation LPF is used in [62] to make legitimate references for battery and diesel systems to smooth the instabilities from a sun situated PV plant. The noteworthy target is to lessen the repeat instability caused as a result of blend of the PV plant with system. It was found that the joined action of battery and diesel generator can effectively mitigate the instability from PV plant meanwhile keeping up the SOC measurement of the battery plant at half.

3. Proposed PV system Ramp control system

The overall system diagram for the PV system can be shown as follows,

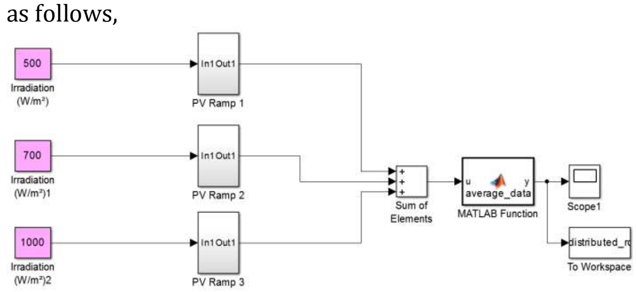


Figure 1. Top level model

From the above figure, we can see that the system is based on a distributed PV model, which is usually the case in real time PV systems. The internal structure of the PV Ramp controller can be seen from the following figure,

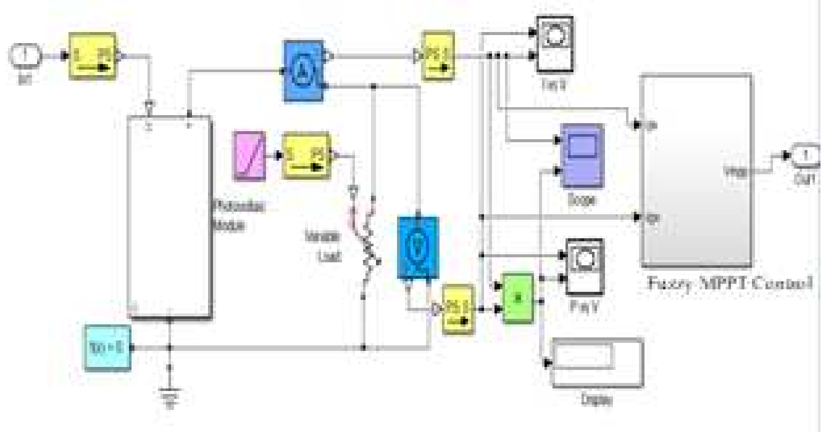


Figure 2. Internal structure of a Fuzzy PV model

This PV ramp control system is applied at each of the distributed PV systems, so that the ramp control can be done locally for each PV module. The PI based ramp control system's output is given to an aggregator module, which smoothens the output waveform by evaluating the mean of the voltage values arriving at the input. The internals of the Fuzzy PI based MPPT controller can be seen from the following figure,

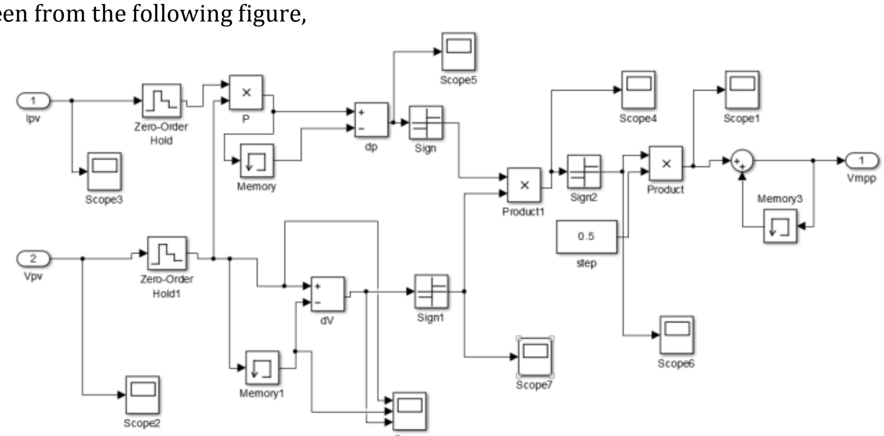
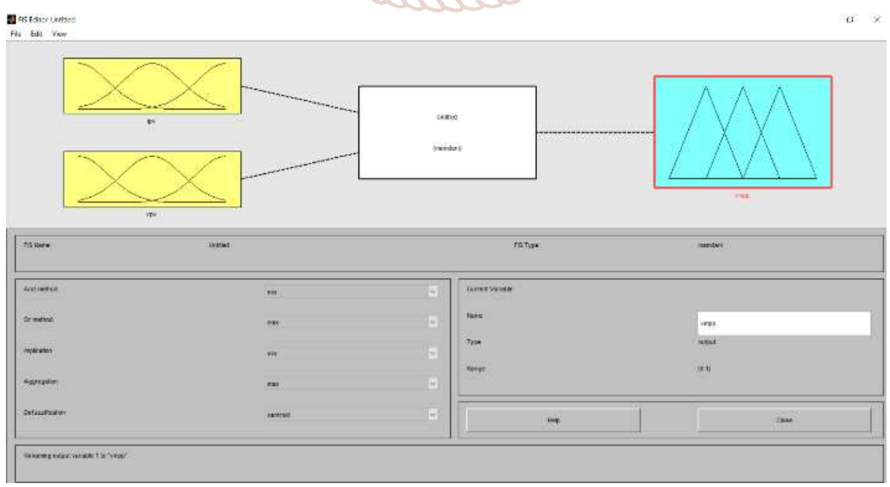


Figure 3. Fuzzy MPPT based PI controller

From the figure, we can observe that the current and voltages are given to a zero-hold circuit, so that any ramp like signals can be filtered, then a differentiator is applied in order to make sure that the signal values do not go beyond a particular level. The output of the differentiator is given to an integrating circuit, wherein the smoothened signals are restored to their original levels. These signals are then given to a Fuzzy MPPT controller in the later part of the figure, where the fuzzy based maximal power point tracking is done, and the final output of the system is obtained. The fuzzy controller can be depicted from the following figure,



From the figure we can observe that the fuzzy controller takes in 2 inputs Vpv and Ipv and produces the output as Vmpp. This maximum power point output is the result of fuzzy system applying rules to the current and voltage values in order to reduce the overall ramps in the system.

Due to this, there are minimal ramps in the output waveform and we get a rampless output signal from the distributed PV system. The next section describes the result analysis of the developed system.

4. Result analysis and conclusion

The system was tested on the following input parameters,

Ir0 = Input Irradiance = 1000 Cd
Isc = Short circuit current = 8.9 Amps
Rs = Series resistance = 0.05 Ohms
Tin = Input temperature = 25 Deg. Cel.
Voc = Output control voltage = 22.75 V
N = Efficiency ratio = 1.2

These parameters are varied and the system was run with and without MPPT based PI control, and the values of output power of the system were tracked. The following figure shows the P v/s V output of all the PV modules,

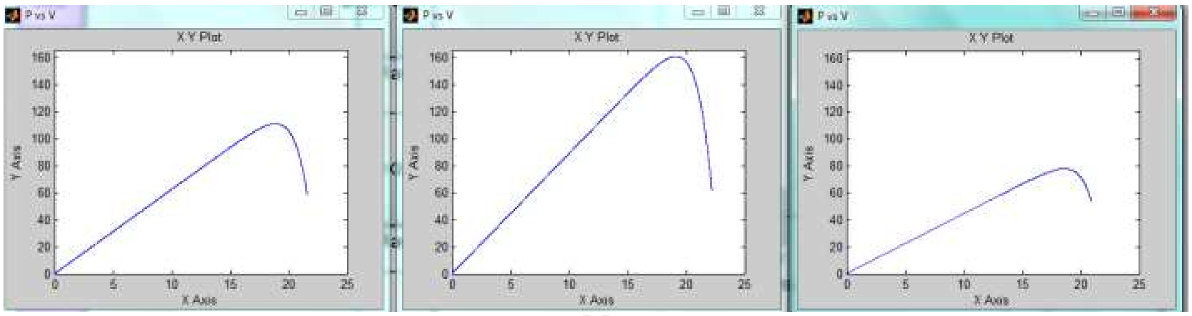


Figure 4. P v/s V output

From the output we can see that the system has different outputs, and is truly distributed in terms of power capabilities. The following figure shows the power output with and without ramp control,

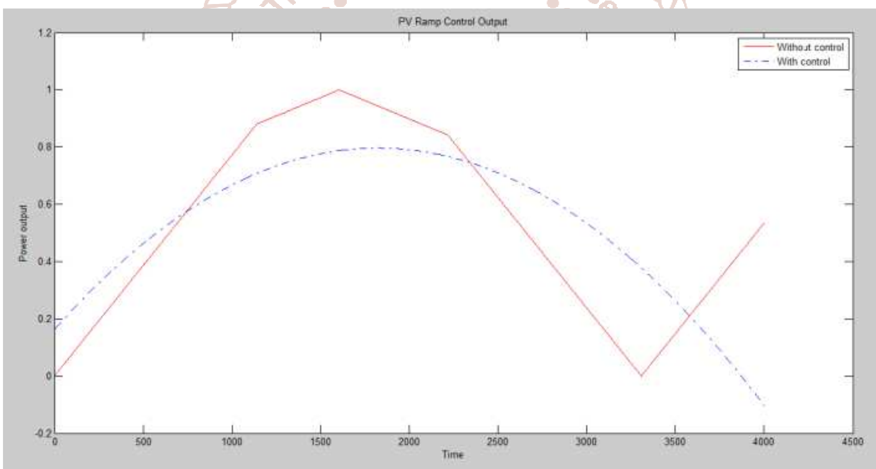


Figure 5. Power output with and without control

From the figure, we can observe that the developed system has higher stability in terms of power control, and thus has better ramp control capabilities. The following figure showcases the output when the input parameters are changed,

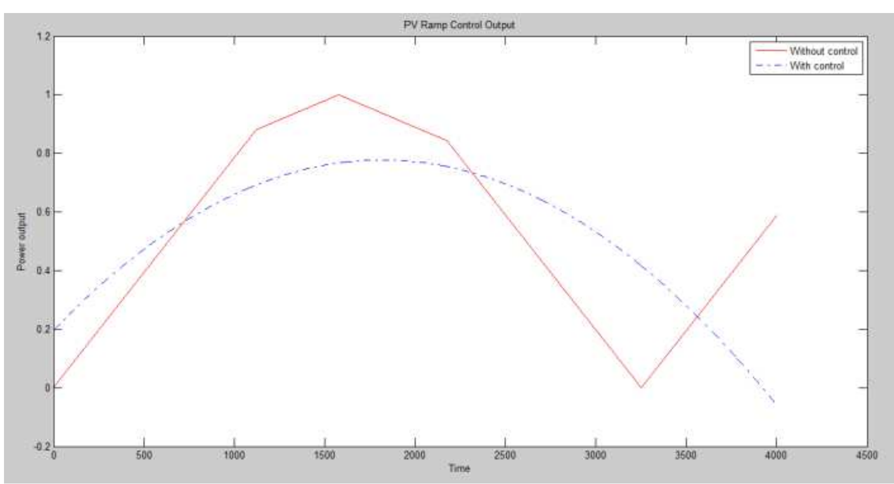


Figure 6. Power output with and without control with value of Tin = 30

As we can see, based on the changing values of the input parameters, the outputs change accordingly, for example if the input temperature is increased then the output power increases, but the ramp capabilities are almost the same, thus our system is capable of removing ramp from the output of PV models. We also compared the results with normal MPPT controller and found the following results,

Tin	Ramp (%) MPPT	Ramp (%) Fuzzy MPPT
25	10%	8%
30	15%	12%
35	22%	18%
40	26%	19%
50	28%	21%

From the table it is clear that the proposed controller reduces the ramp capabilities of the system by more than 10% minimum.

5. Future work

As a future work, researchers can further apply artificial intelligence and machine learning techniques to further enhance the performance of the ramp control system, thereby improving the rate control of the ramp for the PV modules.

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