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Flexible Active Power Control Strategy forPhotovoltaic System Based on Modified Current control

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Abstract: India possesses an abundance of solar energy resources, with an annual output surpassing that of its non-renewable energy sources. As the integration of renewable energy sources into the grid continues to rise, the fluctuations in power, influenced by various operational climate factors such as solar insulation and temperature, become increasingly critical. Given the impossibility of constraining such installations over time, the penetration level of renewable sources is anticipated to grow, fulfilling the demand with eco-friendly energy. This paper presents a flexible power point tracking (FPPT) control of active power in photovoltaic systems to achieve reserve capacity alongside Power Limiting Control (PLC). This combined approach ensures heightened stability within the existing system, preventing overload, and allowing seamless integration into the grid. Additionally, it enables the mitigation of adverse effects stemming from high-level integrations, facilitating modifications to the grid codes instead of requiring the complete replacement of the existing grid infrastructure. The model is developed using the Matlab/Simulink software package, and the effectiveness of the proposed system is validated within the Simulink environment

Keywords: Flexible Power Point Tracking, Maximum Power Point Tracking, Photovoltaic, Perturb and Observe, Power Limiting Control.

I.INTRODUCTION

In the developing countries industrialization and manufacturing and automobiles become major driving forces to done research on clean and renewable energy in order to reduce global worming effect as well as carbon dioxide. Control techniques are generally used to increase power output from PV system in order to utilize available energy in most effective manner. However the amount of power production of PV system during the MPPT operation depends on climate conditions if once operating point reached to MPP there no further flexibility to control and as penetration level of PV system increases in grid there are many adverse effects on stability and power quality[1-2]. Sudden change in environment conditions like passing clouds can cause wild fluctuations of voltage and all PV systems are operating at MPP point then there is no flexibility of frequency control by adjusting power outputs.

As the penetration level increases we need to address issues like voltage fluctuations, frequency changes etc. proper mitigations methods should be implemented instead of updating the existing system[3] as it is very costly. The rapid growth of solar energy installations will inject intermittent power which makes the grid extremely distributed. This make necessity to limit such installations which is against the national interest on renewable energy so need to control active power flexibly to ensure optimal integration of PV system to existing grid. If it is possible to control power output from PV system instantaneously the issues which mentioned above can tackle to great extent so as to ensure a smooth integration of PV system into grid by controlling power flexibly has to be implemented. If any fall in grid frequency because of over loading PV systems have to inject required power instantaneously to maintain grid frequency so it is clear that for grid connected renewable energy sources it is required to adopt various control functions to regulate their power outputs instead of only extracting maximum energy by using energy storage systems it is possible to control power. As storage system can absorb and release energy based on demand but the problem is initial cost and maintenance cost of energy storage system is very high this is big disadvantage. Instead of changing old controllers with new controllers FPPT method is simply adopted by updating the existing grid codes for MPPT to make the system further grid friendly. To meet the potential challenges many countries such as Denmark, Germany, etc. modernised their existing grid codes [4-5].The paper ordered as follows. Section 2 deals with PV characteristics and DCDC boost converter, the conventional P&O MPPT control techniques for deriving the maximum power point (MPP). Section 3 deals with proposed FPPT controlling strategy. In section 4 deals with simulation results of MPPT and FPPT. In the last section, a inference is drawn as FPPT is preferred grid friendly approach.

II.SYSTEM DESCRIPTION AND MODELLING A. Modelling of Photovoltaic System

The modelling of PV system is a significant feature to label performance of the PV systems [6] given a mathematical prototypical defining PV module characteristics in series and parallel combination of equivalent circuit as shown in a Figure 1 for the equivalent PV array, the output current in terms of voltage is expressed given by Equation 1.

The total count of modules which are in series and parallel can be selected based on power requirements.

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Research paper **Volume 11, Iss 12 , 2022**

$$I_{pv} = I_p N_p - I_o N_p \left[e^{\left(\frac{q}{AKT}\left(\frac{V}{N_S}+\frac{I \times R_S}{N_p}\right)\right)} - 1 \right]$$

Where I_{pv}= Photovoltaic array current

I_p = Current in each parallel module

(1)

Np = Number of modules in parallel

Ns = Number of modules in series

K = Boltzmann's constant

T= cell temperature

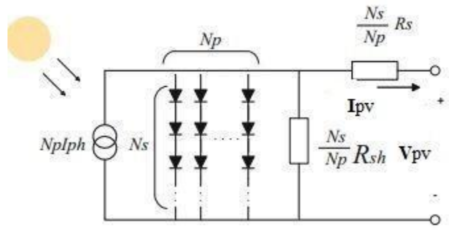

Figure 1 PV Array equivalent circuit

Voltage and Power characteristics equivalent PV array are shown in Figure 2 however in order to get 100KW of total power 10 series and 47 parallel modules per string was Considered to generate 100KW power output when full irradiation available which will be discussed in subsequent sections of this paper.

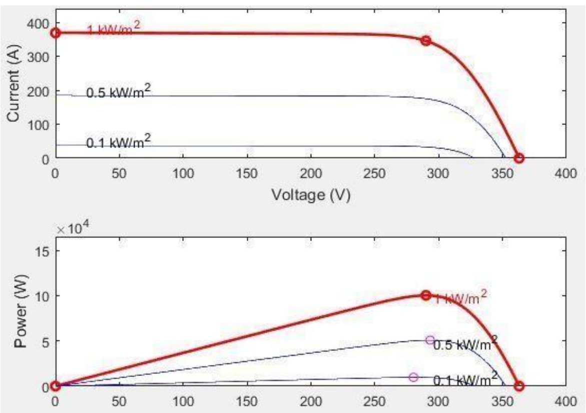

Figure 2 Voltage and Power characteristics PV array

B. DC-DC Boost Converter

As output voltage of PV module is fluctuating in nature as it required to maintain constant input voltage to inverter so it is mandatory to add intermediate interfacing stage and as efficiency of PV cell is less so as to track MPP point is required to extract maximum available power from PV module and is very much necessary which can be processed through a DC-DC converter which is shown in Figure 3 by properly selecting the filter inductor (L) and filter capacitor (C) boost converter output (Vdc) is maintained constant and continuous the output voltage is given by Equation 2 The duty ratio is used to regulate the voltage ratio between the input and output.

$$V_{dc} = \frac{Vpv}{1-D} \quad (2)$$

Where Vdc= DC output voltage

Vpv = PV output voltage

D = duty cycle

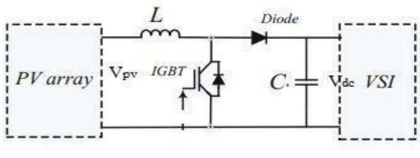

Figure 3 DC-DC Boost Converter

The controller produces a PWM signal that will be amplified by gate driver system to control the switching process.

C. Maximum Power Point Tracking System

The efficiency of solar modules is less its very much required to abstract maximum available power from panel for every PV panel there exist a single point where possible power extraction is maximum (MPP).power available at MPP is depends on solar insulation and terminal voltage of panel is highly temperature dependent since solar insulation and temperature are varying continues throughout the day so a good tracing mechanism of MPP is required to efficiently harvest available power. Various MPPT methods are presented in literature [7, 10]. Figure 4 shows power variations with respect to voltage, unique MPP point, constant current region and constant voltage region. kyny

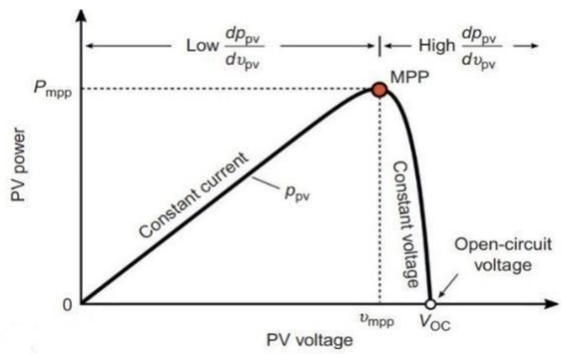

Figure 4 Power-Voltage (P-V) Characteristics

In the literature several MPPT techniques Amongst all the MPPT methods, Perturb & Observe (P&O) most frequently used [12] less cost simple construction makes P&O Algorithm more popular it just measure voltage (Vpv) and current (Ipv) from panel and calculate power and perturb the voltage in required direction with small change in duty cycle until it reach MPP. Finally MPPT algorithms trace the voltage and current of the PV array and then regulate the duty ratio for the DC-DC converter.

III.FLEXIBLE POWER POINT TRACKING PROPOSED CURRENT LIMITING SCHEME

As installation of renewable energy sources which are highly fluctuating in nature which are integrated to old existing grid leads to large power fluctuations old existing grid need to cope up with these fluctuations.

ISSN PRINT 2319 1775 Online 2320 7876

Research paper **Volume 11, Iss 12 , 2022**

The fluctuations in power is because of environmental conditions like change in solar irradiance current grid codes do not allow active contribution of the PV system for grid regulation [13-14] which forced us to bound such installations Though, additional increment of the penetration level of renewable energy systems is needed by utmost countries supposing to meet their national green power plans [15]. One of the best solutions is to control active power flexibly which becoming compulsory task for the PV system demand us to make sure appropriate incorporation of PV systems into the grid. Instead of replacing old existing system and the grid reinforcement measures if the obtainable power of PV systems shell be flexibly controlled then easy incorporation of PV systems into the grid is possible. Flexible active power governing mechanism of PV system can be realized by power limiting control (PLC)[17,18]. In PLC total amount of the power abstraction of the PV systems is restricted to a assured level so that controller will control greatest power that can be pumped by the PV system is within the capacity of grid. This permits further more PV systems to be coupled to the power grid instead of replacing old existing grid. As the system with storage can charge and discharge energy based on load requirements. In this method the energy Storage system can also deliver the active power while the PV production is not available However, the initial investment on the energy storage systems is a main factor to be considered for this methodology. In addition, as aging of energy storage devices (e.g., batteries) may also increases problems concerning the operating costs for maintenance and also reliability of the complete system may effected with aging [16,17]. In fact, it is possible to control power extraction from the PV system in a flexibly way by the control of power converters, particularly in two stage configuration PV systems with DC-DC converters which allow the power control flexibility and the PV power which is extracted should be reduced as it monitored by active power reference It means that the MPPT controller have to be changed during the operation, The operating point of the PV system when tracking the FPP point will be located away from the maximum power point (MPP) this solution is reflected as a cost-effective one so realized active power flexible control of PV systems without additional hardware implementations [18, 19] this method is named as flexible power point tracking (FPPT).

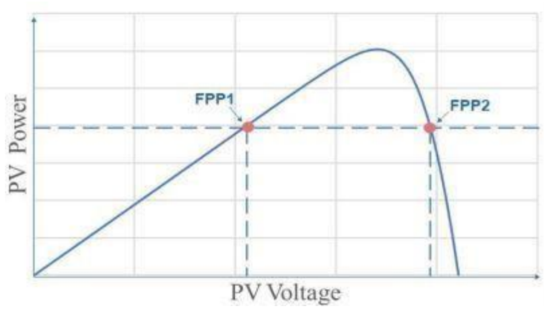

Figure 5 Power-Voltage Characteristic of PV at FPPT

In FPPT there will be two different operating points FPP1 and FPP2 as shown in Figure 5.The dual operational points will exhibits dissimilar dynamics [20.21], on which PV systems are controlled to operate. Relating the two possible operating points, the inclination of the P-V typical curves at right side of the MPP point is far greater Thus, the power fluctuation in the steady state will be greater after. The PV system is fixed at operate point FPP2 there will be enormous oscillation means lower accurateness, increased power losses but operating the PV system at FPP1 gives a relatively less steady output voltage[22, 23] it will out comes in low input voltage for the DC-DC converter. The principle of operation is stated in Equation 3.

$P_{pv} = P_{mppt}$ when $P_{pv} < P_{limit}$

$P_{pv} = P_{limit}$ when $P_{pv} > P_{limit}$ (3)

The block diagram of proposed system with MPPT controller is presented in Figure 6 which consist of DC-DC converter, MPPT block PI controller and a comparator , V ref will be generated by MPPT block and error will be feed to a PI controller which will compare with a triangular carrier signal to generate required duty cycle by controlling IGBT .

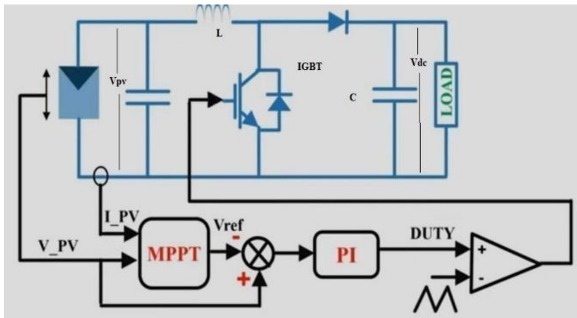

Figure 6 Block diagram of model with MPPT control technique.

Extracted PV power will be limited to certain value can be controlled by controlling the output current of PV array after a careful observation on PV array characteristics Vpv dependence on solar irradiation is very small but Ipv highly sensitive to solar irradiation (i.e. directly proportional) by this observation limiting the PV output current to a required reference level in a operating region which is on the right side of the MPP (i.e. FPP2) can effectually restrict the power output of PV array . The output current of PV module is limited by saturation as shown in block diagram in Figure 7 the saturation level is based on selective grid requirements.

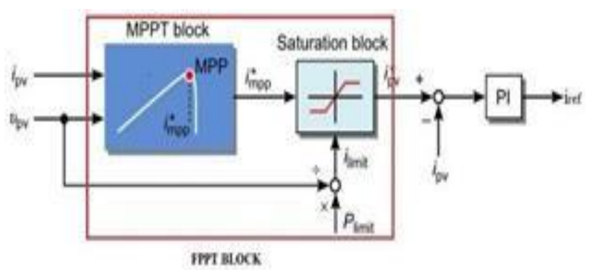

Figure 7 Block diagram of proposed current limiting controller for FPPT

The strategy based on PLC through the current limiting technique was realized here as shown in Fig8.by implementing this controller to existing MPPT we can limit the output power to Plimit. Ilimit can be calculated by equation 4.

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Research paper **Volume 11, Iss 12 , 2022**

$$I_{limit} = \frac{P_{limit}}{V_{pv}} \quad (4)$$

P-V paths with the announced PLC based current controller method are shown in FIGURE 8 with 80% of the rated the power limit.

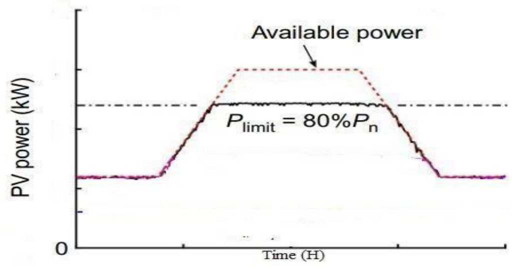

Figure 8 PLC based current controller with power limit of 80%.

I. SIMULATION RESULTS OF MPPT AND FPPT

The proposed model was simulated in Matlab/Simulink environment. The specifications of the detailed model which is used for simulation are shown in Table I.

TABLE I

S.No	PARAMETER	VALUE
1	Rated Power	100KW
2	DC-DC Converter Inductance	1.45mH
3	DC-DC Converter Capacitance	3200uF
4	Switching Frequency	5kHZ
5	DC link Voltage reference	700V
6	series modules parallel strings	10 47
7	Open Circuit Voltage of each module	36.3V
8	Short circuit current of each moduel(Isc)	7.84A

After simulating proposed model with MPPT operation it had been witnessed that the PV array output always attempts to reach Maximum power that can be extracted from the PV panel subjected to irradiation available with oscillations around MPP point as shown in Figure 9. Irradiation which is available is 1 KW/M which will generate a power of 100 KW as per modules arrangement as mentioned in Table I.

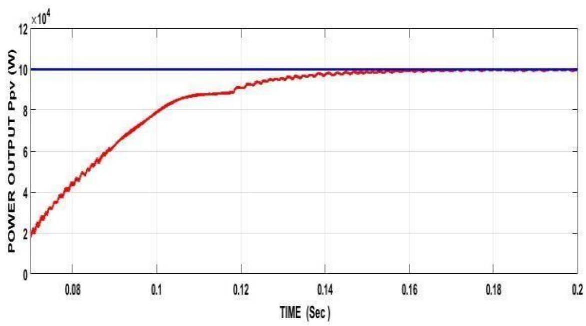

Figure 9 Simulation results of MPPT with 1 KW/M irradiation

As irradiation varies because of passing clouds for a small duration from 0.2 seconds to 0.25 seconds it can be understood that the power extraction from PV modules also reduced proportionally which can be seen in the Figure 10.

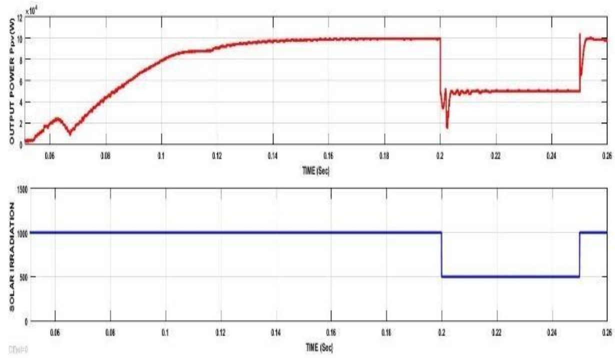

Figure10 Simulation results of MPPT with varying Irradiation.

The reference voltage of 700V is achieved at output of DCDC boost converter as shown in Figure11 Which will be converted to three phase AC by a VSI in next stage. Though there is fall in irradiation at 0.2 seconds but variation at output voltage of DC-DC converter is very small so controller maintaining required proper DC voltage irrespective of disturbances on PV modules.

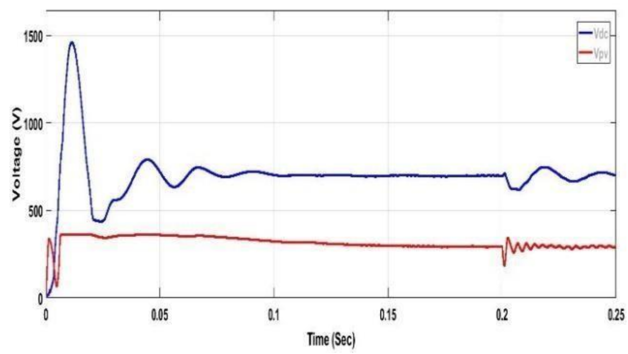

Figure 11 Simulation results of PV voltage and DC link Voltage with MPPT

After simulating proposed model with FPPT operation at 80% limit we had detected that the output of the PV panel constantly attempts toward extraction 80% of extreme available power from the PV array subjected to irradiation available with oscillations around FPP point as shown in Figure 12. Though available Irradiation 1 KW/M which can generate a power of 100 KW as per modules still amount of power which is available at module is only 80KW which is shown in FIGURE 10.

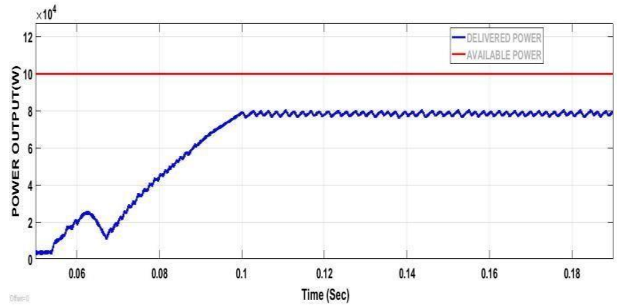

Figure 12 Simulation results of proposed FPPT at 1KW/M² irradiation

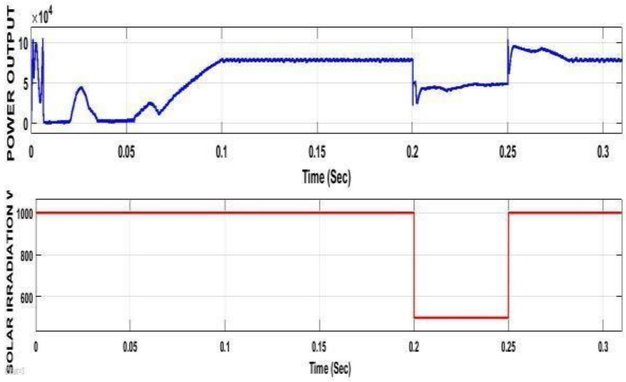

Figure 13 Simulation results of proposed FPPT with varying irradiation

The reference voltage of 700V is achieved at output of DCDC boost converter as shown in FIGURE 14.It can be observed that the PV voltage at FPPT is more than MPPT because operating voltage is moved to right to MPP such that at FPP2 so controller tracking the required FPPT condition as mentioned in proposed method.

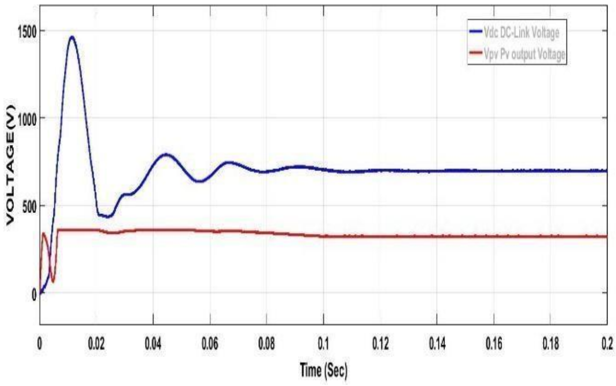

Figure 14. Simulation results of PV voltage and DC link voltage with FPPT

By careful observation of simulated results from Figure10 and Figure13 the inferences which can be drawn are tabulated shown in Table II which shows Extracted Power with MPPT & FPPT with respect to Irradiation. It can be clinch that there serve capacity available in MPPT is always zero as in case FPPT it's available depends on P_{limit}.

TABLE II

S. No	Irradiation (KW/M2)	Extracted with Power MPPT(KW)	Extracted with Power FPPT(KW)
1	1	100	80
2	0.9	90	80

IV. CONCLUSION

The output power from PV system is maximum during MPPT operation however the increasing the installation of renewable energy sources like PV optimised power flow is must instead of grid reinforcement measures. The active power which was available with the PV array can be flexibly controlled, specifically in double-stage PV systems with DCDC converters by changing existing grid codes of MPPT with FPPT this will increases the reserve capacity of system with this reserve capacity we can increase inertia of whole system to regulate the frequency variations grid voltage fluctuations, mitigate grid power quality issues and also enable grid friendly systems.

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