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AN OVERVIEW OF MODERN TECHNIQUE OF CONSTANT POWER GENERATION CONTROLLER FOR GRID INTERACTIVE – SOLAR PV SYSTEM FOR SUSTAINABLE AGRICULTURE AND RURAL DEVELOPMENT

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Abstract

Clean electricity generation is now the prior focus in many countries. Solar PV and Wind Turbines have proved to be successful replacements supporting renewable market. Remarkable research activities are under process to solve the loopholes. Power distributors are now focused to ensure fast and smooth transformation between maximum power point tracking and constant power generation so the maximum feeding power of PV systems must be limited in agriculture nd rural development. Irrespective of variable solar irradiance, Optimum performance and stable operations are achieved by adopting the control algorithm described in this paper. In this strategy, output power from PV system can be optimised and regulated according to desired set point and compel the electrical parameters to operate at left side of maximum power point graphically, without any stability issues. Constant power generation (CPG) control is much effective strategy in terms of stable transitions, high accuracy and fast dynamics which have been verified by results.

Keywords

Active power control, Constant Power Control (CPG), Maximum Power Point Tracking (MPPT), Photovoltaic (PV) systems, PV Inverter

I. INTRODUCTION

With an imperative demand of clean and reliable electricity generation in some countries, the increasing adoption of new photovoltaic (PV) systems pushes the Distribution System Operators (DSOs) to expand the transmission/distributed lines. However, the potential cost brought by such extensions and increased maintenances introduce new obstacles. It can contribute to a weakened requirement of grid expansion and at the same time an increased penetration level. As a result, to meet the required of this emerging additional service provided by future PV systems, a Constant Power Generation (CPG) control concept of PV inverters is proposed. [1]

Accordingly, the following areas will be focused upon as mention in image below:

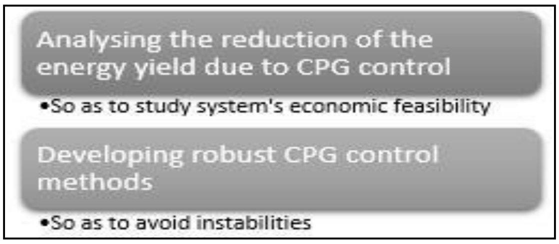


Figure 1: Research Objectives

Maximum Power Point Tracking (MPPT) is effective for PV inverters to maximize the energy harvested from PV panels. However, with increasing installations of PV systems into the grid, many issues, as shown in figure 2, have appeared for the cases when the inverters keep operating at MPPT mode even when the control is within the rated power range.

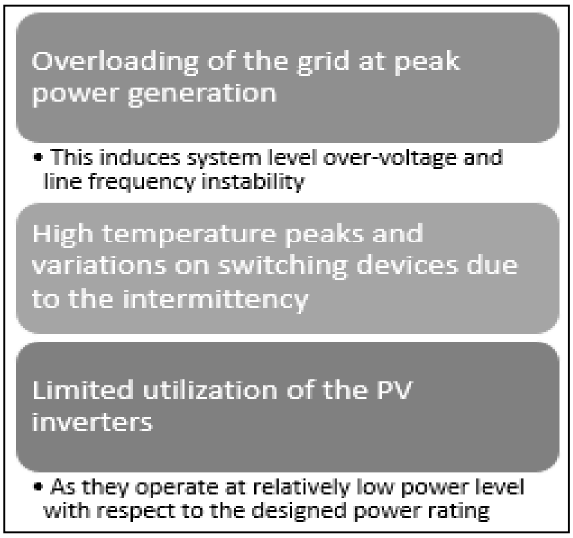


Figure 2: Issues with MPPT algorithms

Study of many researches has shown that the problem like overloading, and losses can be tackled by implementing few of the things mentioned in the figure 3. This paper proposes MPPT-CPG control concept, as shown in figure 4, which allows a reduction of thermal performance and increase the utilization factor of PV inverters.

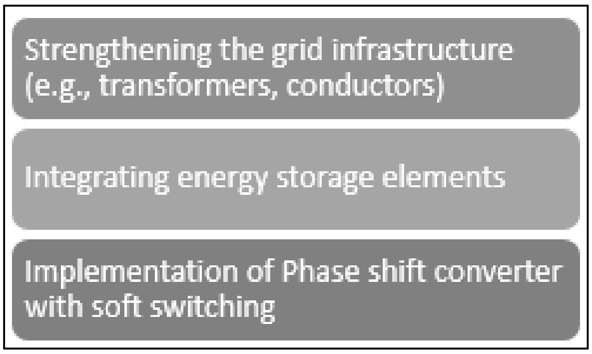


Figure 3: Methods for solving problems related to MPPT

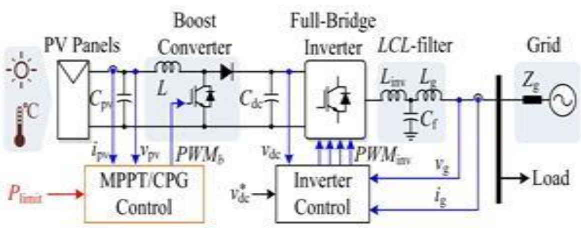


Figure 4: Control Structure of 2 stage 1-phase Grid connected PV systems

The feature presented by the method is shown in figure 5. Meanwhile, mixed implementation of MPPT-CPG, could contribute to the system level power management to some extent, since its role in smoothing and limiting the power fed into the grid. [3]

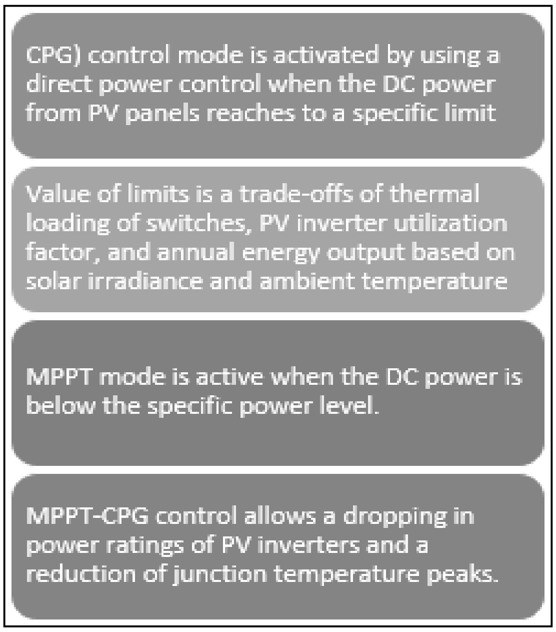


Figure 5: Outcomes of MPPT_CPG control

I. PRINCIPLE OF THE P&O-CPG ALGORITHM

The working principle of the P&O-CPG algorithm, where the operating point is regulated to the left side of the MPP considering stability issues. It can be divided into two modes:

a) MPPT mode($P_{pv} \leq P_{limit}$), where the PO algorithm should track the maximum power.

b) CPG mode($P_{pv} > P_{limit}$), where the PV output power is limited atP_{limit}.

During the MPPT operation, the behaviour of the algorithm is similar to the conventional PO MPPT algorithm - the operating point will track and oscillate around the MPP In the case of the CPG operation, the PV voltage V_{pv} is continuously perturbed toward a point referred to as Constant Power Point (CPP), i.e., ($P_{pv} = P_{limit}$). After a number of steps, the effective point will reach and oscillate around the CPP. Even though the PV system with the PO-CPG control can run at both CPPs, only the operation at the left side of the MPP is focused for the stability concern. PV can be expressed as where MPPT is the reference voltage from the MPPT algorithm (i.e., the PO MPPT algorithm), V_{pv} is the measured PV voltage, and step is the perturbation step size.

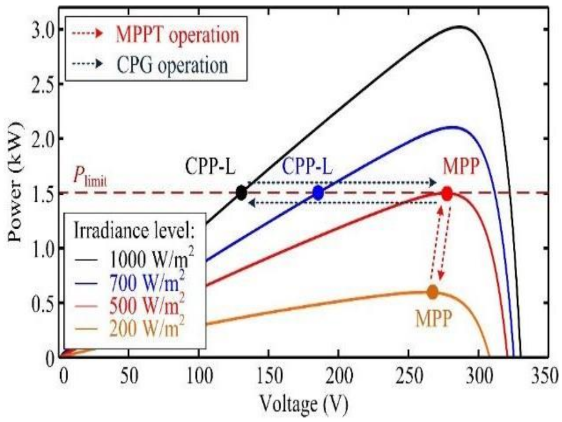


Figure 6: P-V Curve for Various Irradiance

Two major tasks are: reducing the overshoots and reducing the power losses during the fast changing irradiance condition which has to be addressed in the case of CPG operation. The proposed high- performance P & OCPG algorithm can effectively solve those issues. [4]

Increasing the perturbation step size is a possibility to minimize the overshoots as the tracking speed is increased Specifically; a large step size can reduce the required number of iterations to reach the corresponding CPP. Notably, the step size modification should be enabled only when the algorithm.

II. IMPLEMENTATION OF SYSTEM

The PV Array block outfits an array of photovoltaic (PV) modules. The array is fabricated of strings of modules coupled in parallel, each string consisting of modules connected in series. The PV Array block has two inputs that permit to supply varying sun irradiance (input *Ir* in W/m^2) and temperature (input *T* in deg. C) data. The PV Array comprises of eight strings and each string contains six BP SOLAR BP365TS modules connected in series. At 25 deg. C and with a solar irradiance of 1000 W/m^2, the string can produce 3000 W. PV array output Voltage is 66V. The output DC voltage is lower magnitude for Solar PV array. Hence a boost converter is required for boosting the voltage to higher level without use of the transformer. An inductor, a diode and a high recurrence switch constitutes the primary elements of the support converter. PV panel is connected to boost converter. The P & O Algorithm CPG control is implemented in the boost converter to improve the performance of the topology using Simulink model shown in figure 3. Then DC voltage is applied to the full bridge inverter where DC supply is converted into AC. Output of a Inverter is controlled through PWM control system. Then output of inverter is fed to LCL filter where output signals are filtered and then fed to the grid and single phase load is connected at the load end.

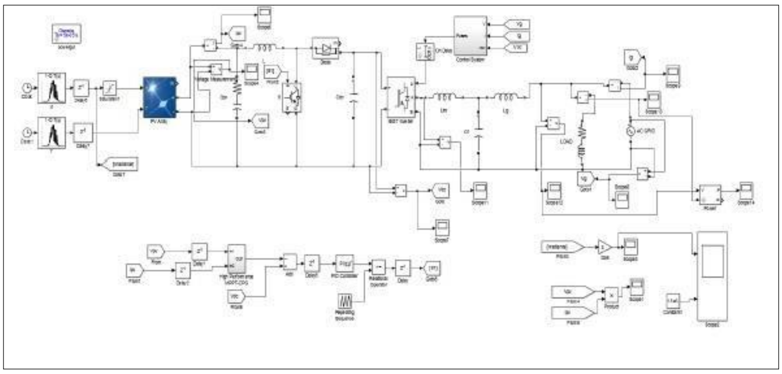


Figure 7: Simulation diagram for two-stage single- phase grid-connected PV system

According to the aforementioned, two main tasks exist minimizing the overshoots and minimizing the power losses during the fast changing irradiance condition, which has to be addressed in the case of CPG operation. Increasing the perturbation step size is a possibility to minimize the overshoots as the tracking speed is increased. Specifically, a large step size can reduce the required number of iterations to reach the corresponding CPP. Notably, the step size modification should be enabled only when the algorithm detects a fast increase in the irradiance condition.

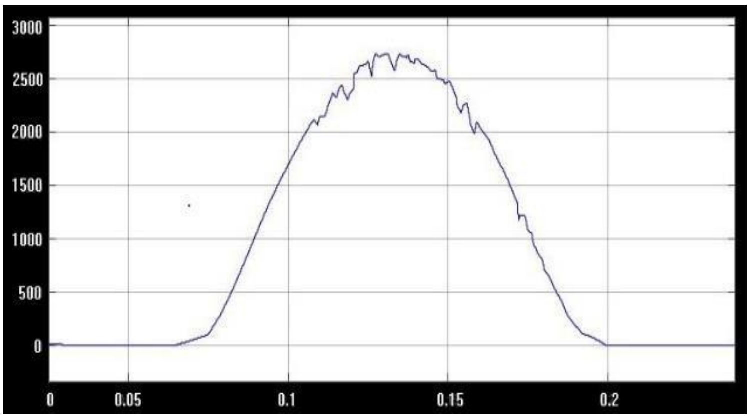


Figure 8: Plot of Solar Irradiance Applied

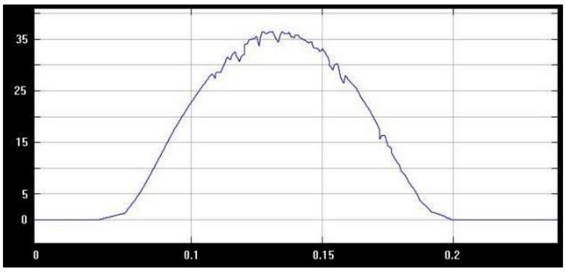


Figure 9: Plot of Nominal PV Module Temperature

By doing so, the large step size will be used initially and the step size will continuously be reduced as the operating point approaches to the CPP.

$$v_{pv}^{*} = v_{pv,n} - \left[(P_{pv,n} - P_{limit}) \frac{P_{limit}}{P_{mp} \cdot \gamma} \right] \cdot v_{step}$$

where *v*pv is the reference output voltage of the PV arrays, *v*pv,*n* and *P*pv,*n* are the measured output voltage and power of the PV array at the present sampling, respectively. *P*mp is the rated power. *v*step is the original step size of the P&O-CPG algorithm. The term *P*limit/*P*mp is introduced to alleviate the step size dependence in the level of *P*limit. *γ* is a constant that can be used to tune the speed of the algorithm.

III. SIMULATION RESULTS

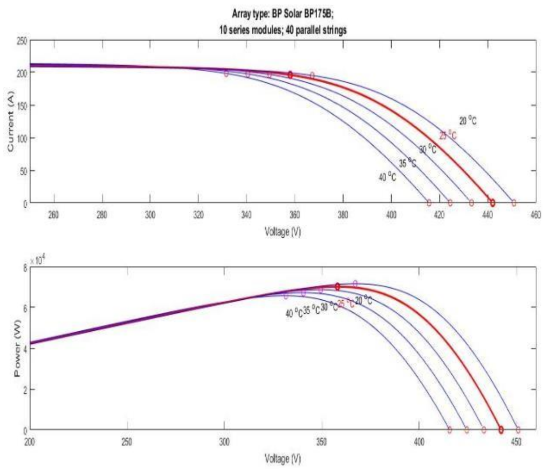
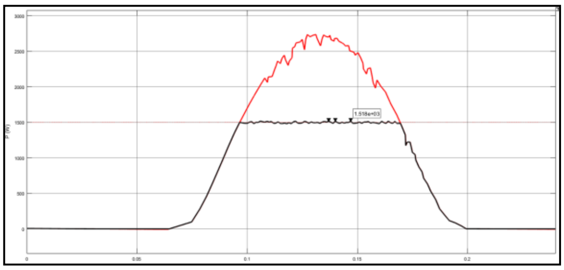


Figure 10: I-V and P-V characteristics of Solar PV Panels

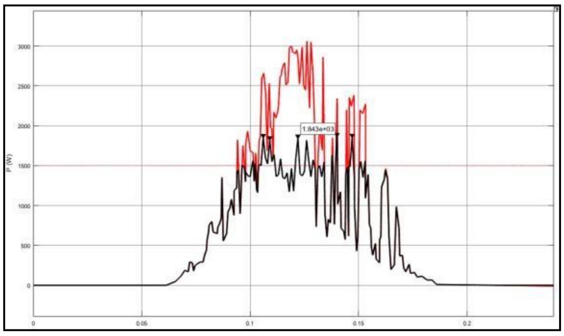
Maximum Power (W)	65.25 W
Cells per module	(Ncell) 18
Short-circuit current Isc (A)	8.1 A
Open circuit voltage Voc (V)	11 V
Voltage at maximum power point Vmp (V)	8.7 V
Current at maximum power point Imp (A)	7.5 A
Shunt resistance Rsh (ohms)	49.9925
Series resistance Rs (ohms)	0.13134
No. of Parallel strings	8
Series-connected modules per string	6

TABLE I. PV Module Parameters

In Fig 7 Simulation diagram for two-stage single- phase grid-connected PV system is presented. Fig. 11 (a & b) shows the performance of the proposed high performance P&O-CPG method with two daily conditions. In contrast to the conventional P&O- CPG method, the overshoots and power losses are significantly reduced by the proposed solution and a stable operation is also maintained. The algorithm also has a selective behaviour to only react, when the fast irradiance condition is detected. Figure 8, 9 and 10 shows the conditions at which PV module was operated and also Table I shows PV module parameters.



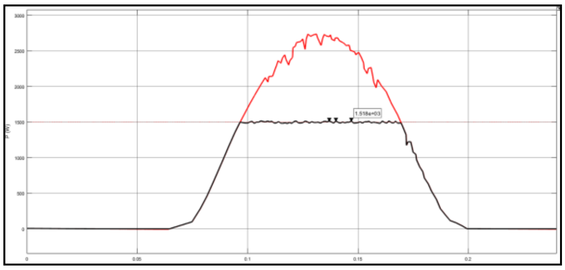
(a)



(b)

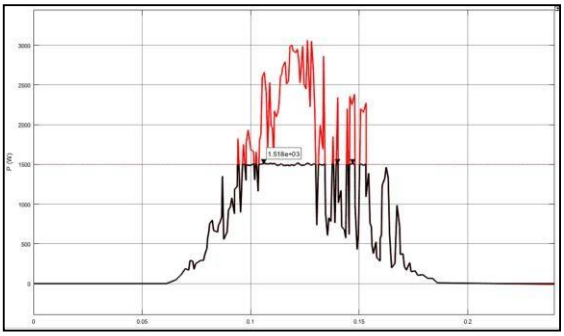
Figure 11: Results of the P&O-CPG algorithm under two daily conditions: (a) clear day and (b) cloudy day.

When the CPG operating point is at the left side of the MPP, the P&O-CPG algorithm requires a number of iterations to reach the new MPP during a fast decease in irradiance, leading to power losses. In fact, the operating point of the PV system does not change much if the PV system is operating in the MPPT under different irradiance levels. The value of εss can be chosen as 1–2% of the rated power of the PV system, which is normally higher than the steady-state error in the PV power of the P&O-CPG algorithm.When a fast decrease is detected during the CPG to MPPT transition, a constant voltage is applied to the PV system in order to accelerate the tracking speed (i.e., minimize the power losses). The constant voltage can be approximated as 71–78% of the open- circuit voltage V_{OC}. By doing so, the operating point can be instantaneously moved close to the MPP in one perturbation, resulting in a significant reduction in the number of iterations until the operating



point reaches the MPP. This approach is simple but effective, which is very suitable to be implemented.

(c)



(d)

Figure 12: Results of the proposed high-performance P&O- CPG algorithm under two daily conditions: (c) clear day and (d) cloudy day

CONCLUSION

A high-performance active power control scheme by limiting the maximum feeding power of solar PV systems for sustainable agriculture and rural development has been proposed in this paper. The proposed solution can ensure a stable constant power generation operation. Compared to the traditional methods, the proposed control strategy forces the PV systems to operate at the left side of the maximum power point, and thus it can achieve a stable operation as well as smooth transitions. Experiments have verified the effectiveness of the proposed control solution in terms of reduced over-shoots, minimized power losses, and fast dynamics. Notably, for single-stage solar PV systems, the same CPG concept is also applicable. However, in that case, the PV voltage operating range is limited and minor changes in the algorithms are necessary to ensure a stable operation.

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