

Grid Connected PV Inverter with Hybrid MPPT, CPG Power Control Concept: A Review

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ABSTRACT: This paper describes the connected photovoltaic (PV) power generation system's grid overvoltage protection function and summarizes the occurrence of the output power loss due to the grid voltage rise. Power injection from the PV system will raise the voltage at the power distribution line. A power conditioning subsystem needs to regulate its output if the voltage becomes higher than the upper limit in order to avoid the overvoltage at the power grid. Thus, a PV system cannot generate electricity under the high grid voltage. The causes of this maldistribution of the output energy loss are the difference of the line impedance, the difference of the starting voltage of the PCS's grid overvoltage protection function, and the imbalance of the load in single-phase three-wire power distribution systems. The present control of the PCS successfully avoids the overvoltage on the grid but cannot share the loss. The control strategy is based on either a maximum power point tracking controller or a constant power generation (CPG) control depending on the instantaneous available power from the PV panels.

KEYWORDS: PV Cell, Boost converter, CPG, MPPT Controller.

I. INTRODUCTION

MAXIMUM power point tracking (MPPT) is effective for photovoltaic (PV) inverters to maximize the energy harvested from PV panels. However, with increasing installations of PV systems into the grid, the following issues appear if the inverters keep operation at MPPT mode even within the rated power range: 1) overloading of the grid at peak power generation which may induce system level over-voltage and line frequency instability; 2) limited utilization of the PV inverters, since they operate at relatively low power level with respect to the designed power rating during most of long-term field operations; 3) high temperature peaks and variations on switching devices due to the intermittency, which accelerates the degradation of the switching devices. The PV generator should normally operate in the MPPT mode. A photo-voltaic array is a linked assembly of PV modules. Most PV array use an inverter to convert the dc power produced by the modules into alternating current. The modules in a PV array are connected in series to obtain the desired voltage, the individual strings are then connected in parallel to allow the system to produce more current. It is the purpose of a MPPT system to sample the output of the cells and determine a resistance to obtain maximum power for any given environmental conditions. A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point technique is used to improve the efficiency of the solar panel. The inverter device with the function of maximum power point tracking can inverse the electrical power into sinusoidal current and connect to the grid. This hybrid MPPT-CPG power control concept with the objective to overcome overloading and increase the utilization factor of PV inverters. It has the following features: 1) A constant power generation (CPG) control mode is activated by using a direct power control when the dc power from PV panels reaches to a specific limit. PV inverter utilization factor and annual energy yield under yearly mission profiles (i.e., solar irradiance and ambient temperature). It should be noted that the selection of this power limit is different from those in and as discussed above. 2) The MPPT mode is active when the dc power is below the specific power level. The proposed MPPT-CPG control concept of PV. Meanwhile, it could contribute to the system level and limiting the power fed into the grid.

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II.METHODOLOGY

A) MPPT, CPG Controller:-

The control system mainly controls the maximum power point tracking of photo-voltaic, current waveform and power of the output of grid connected inverter, which makes the output of the grid corresponding with the export by PV array. MPPT is not a mechanical tracking system that “physically moves” the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power current. Maximum Power Point Tracking (MPPT) is an algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. MPPT is effective for photovoltaic (PV) inverters to maximize the energyharvested from PV panels but if the inverters arekept in operation at MPPT mode even within therated power range the grid gives rise to issues suchas overloading of the grid at peak power generation,limited utilization of the PV inverters and hightemperature peaks and variations on switchingdevices. The overloading issue can be overcome byusing the MPPT control with a reduced power mode control and MPPT control with powercurtailment control. However, the issue on theutilization and thermal performance of PV inverterremains. The single-phase two-stage configuration is preferable for residential PV applications. The control structure of a two stage single-phase PV system with the proposed control concept is shown in Fig.which indicates that the hybrid control strategy is implemented in the control of the boost stage.Depending on the instantaneous available power of the PV panels, the actual output power of the PV panels can be expressed as

$$P_0(t) = P_{PV}(t), \text{ MPPT}, P_{pv}(t) < P_{limit}$$

$$= P_{limit}, \text{ CPG}, P_{pv}(t) \geq P_{limit}$$

Where $P_0(t)$ is the o/p power of the PV panels.

As the available PV power is weather-dependent, the operation modes will alter accordingly with the solar irradiance and ambient temperature. Fig exemplifies different operation regions for a single-phase PV system during a day with the proposed control strategy. Then, according to (1), it can be obtained that

$$E_{mpp} = \int_{t_0}^t P_{pv}(t) dt$$

$$E_{cpg} = \int_{t_1}^{t_2} P_{limit} dt + \int_{t_3}^{t_4} P_{limit} dt$$

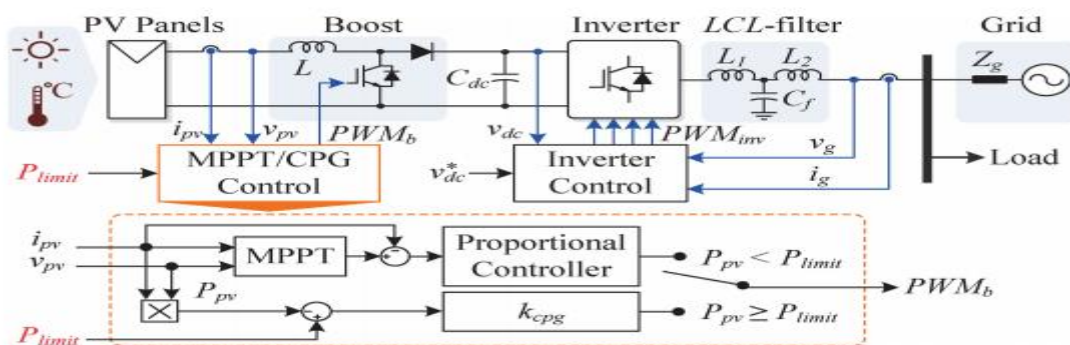


Fig.1 Schematic and control dig of a two-stage signal-phase PV system with the proposed hybrid control concept

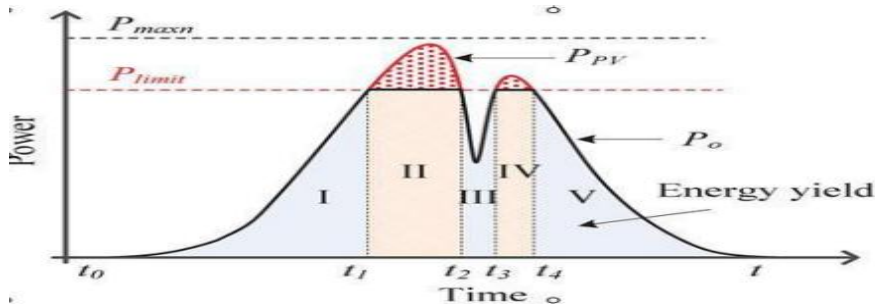


Fig 2. Operation regions (I, III, V - MPPT; II, IV - CPG) for a single-phase PV system during a day with the proposed control concept, where P_{lim} is determined by the tradeoffs among the device thermal performance, the inverter utilization factor, and the annual energy yield.

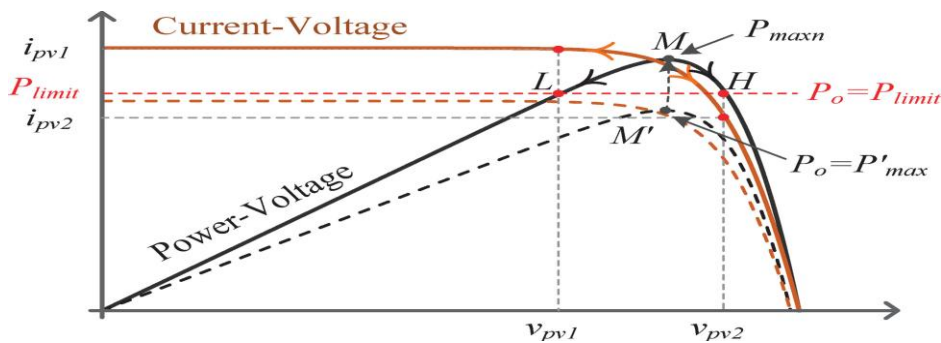


Fig 3 PV characteristics with limiting maximum feed-in power control

where E_{mpp} is the available energy during a day with MPPT control, and E_{cpg} is the energy production in CPG operation mode in regions of II and IV in Fig. 4. Hereby, the “cut-off” energy (dotted-area) during the day can be given by

$$E_{ess} = \int_{t_0}^{t_2} P_{pv}(t) dt + \int_{t_3}^{t_4} P_{pv}(t) dt - E_{cpg}$$

which can be adopted as a trade-off factor to determine the power limit P_{limit} . According to Figs. 1 and 2, and (1), the operation principle of the proposed hybrid MPPT-CPG control can be described as follows. When $PPV(t) \geq P_{limit}$, the system enters into CPG operation mode and the MPPT control is deactivated. The PV output power is regulated by a proportional controller (k_{cpg}) to maintain the output power constant (i.e., $P_o(t) = P_{limit}$). When $PPV(t) < P_{limit}$, the system maximizes the output power with an MPPT control, and thus the CPG control is disabled.

B) PV Cell- Conversion of light energy in electrical energy is based on a phenomenon called photovoltaic effect. When semiconductor materials are exposed to light, some of the photons of light ray are absorbed by the semiconductor crystal which causes significant number of free electrons in the crystal. This is the basic reason of producing electricity due to photovoltaic effect. Photovoltaic cell is the basic unit of the system where photovoltaic effect is utilized to produce electricity from light energy. Silicon is the most widely used semiconductor material for constructing photovoltaic cell. Free electrons and holes have vital role in creating electricity in photovoltaic cell. These electrons and holes are hence called light-generated electrons and holes respectively. These light generated electrons and holes cannot produce electricity in the silicon crystal alone.

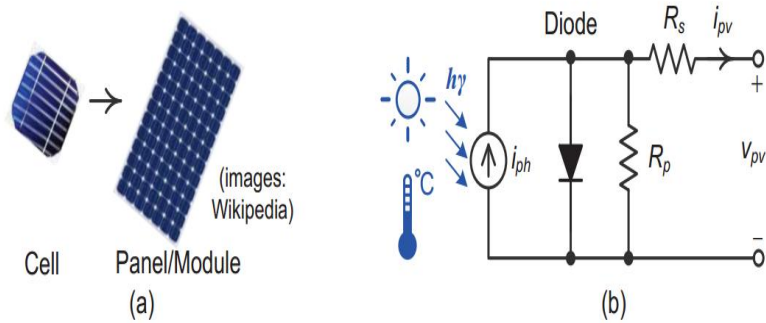


Fig 4 PV module: (a) physical model (b) equivalent circuit of the module

C) Boost Converter-The boost converter is used to "step-up" an input voltage to some higher level, required by a load. This unique capability is achieved by storing energy in an inductor and releasing it to the load at a higher voltage. This brief note highlights some of the more common pitfalls when using boost regulators. These include maximum achievable output current and voltage, short circuit behavior and basic layout issues. The references at the end of this document provide excellent overviews of the operation of a boost regulator; and should be consulted if the reader is not familiar with the basic operation of this type of converter.

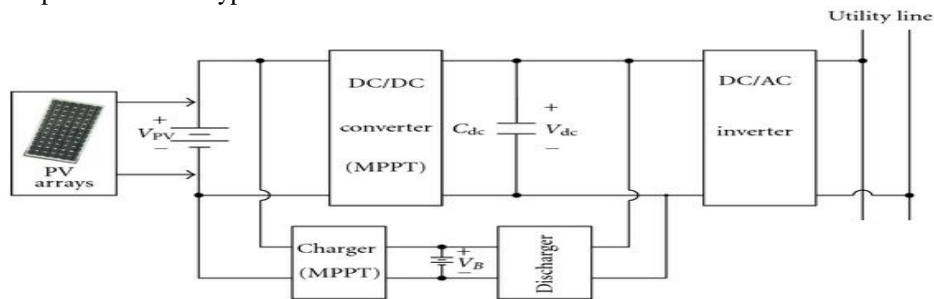


Fig 5 Boost Converter

III. LITERATURE REVIEW

A. Ahmed, L. Ran, S. Moon, and J.-H. Park "A fast PV power tracking control algorithm with reduced power mode," IEEE Trans. Energy Conversions., vol. 28, no. 3, pp. 565– 575, Sep. 2013.

This paper presents a fast maximum power point tracking (MPPT) control algorithm for the photo-voltaic (PV) in a hybrid wind-pv system, in which the PV generator may also need to work in a reduced power mode (RPM) to avoid dynamic overloading. Since direct duty ratio control of the PV generator based on hill-climbing algorithms was described as a very advantageous method due to its simplicity and ease of implementation, it was chosen as the base of the control algorithm for the PV generator in this paper. Transient analysis and perturbation parameter design for this proposed method have been carried out. From the analysis, it is seen that the proposed method can guarantee better performance of the hill climbing MPPT controller than the conventional. Also, it was found that the MPPT efficiency is increased, while the power fluctuation is reduced. The MPPT controller incorporating an RPM algorithm was developed in consistence with the previous design of the perturbation parameters.

R. Tonkoski, L. A. C. Lopes, and T. H. M. EL-Fouly, "Coordinated active power curtailment of grid connected PV inverters for overvoltage prevention," IEEE Trans. Sustain. Energy, vol. 2, no. 2, pp. 139–147, Apr. 2011. This paper discusses the use of droop-based active power curtailment techniques for overvoltage prevention in radial LV feeders as a means for increasing the installed PV capacity and energy yield. Co-ordinated active power curtailment of grid

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connected PV inverters for overvoltage prevention has been discussed here. Two schemes are proposed and tested in a typical 240-V/75-kVA Canadian suburban distribution feeder with 12 houses with roof-top PV systems.

Y. Yang, H. Wang, and F. Blaabjerg, "Reduced junction temperature control during low voltage ride-through for single-phase photo-voltaic inverters," IET Power Electron., pp. 1–10, in press, 2014. DOI: 10.1049/ietpel. 2013.0734.

This paper have discussed a Junction Temperature Control concept for the switching devices in a single-phase PV inverter in order to reduce the junction temperature stress, and thus to achieve improved reliability of a PV inverter. An approach to achieve a reduced or constant junction temperature of the switching devices in a single-phase PV inverter has been proposed in this paper. The controlled constant junction temperature and reduced temperature swings allow a further improved reliability of the PV inverter and an improved robustness of the PV system in response to abnormal grid conditions (e.g. low-voltage ride-through). By appropriately injecting reactive power to the grid during ride-through operation, the single-phase PV inverter would not be at the risk of over-current protection and therefore with a better grid support capability.

D. Sera, L. Mathe, T. Kerekes, S. V. Spataru, and R. Teodorescu, "On the perturb-and-observe and incremental conductance MPPT methods for PV systems," IEEE J. Photo-voltaic, vol. 3, no. 3, pp. 1070–1078, Jul. 2013. This paper presents a detailed analysis of the two most well-known hill-climbing Maximum Power Point Tracking (MPPT) algorithms: the Perturb-and-Observe (P&O) and Incremental Conductance (INC). The two methods are thoroughly analysed both from a mathematical and practical implementation point of view. Their mathematical analysis reveals that there is no difference between the two. The results show that despite the common opinion in the literature, the P&O and INC are equivalent.

H. Wang, M. Liserre, F. Blaabjerg, P. de Place Rimmen, J.B. Jacobsen, T. Kvisgaard, and J. Landkildehus, "Transitioning to physics-of-failure as a reliability driver in power electronics," IEEE J. Emerging Sel. Topics. Power Electron.vol. 2, no. 1, pp. 97–114, Mar. 2014. This paper serves to give an overview of the major aspects of reliability in power electronics and to address the future trends in this multidisciplinary research direction. Reliability is an important performance index of power electronic systems. The status and future trends of the DFR (design for reliability) in power electronics are presented in this paper.

IV. CONCLUSION

A new MPPT-CPG control concept is proposed for grid connected PV inverters by considering the long-term mission profiles and the system level power management requirements. The proposed control strategy enables to increase the utilization factor of PV inverters and to reduce the temperature variations on power devices. Moreover, it is beneficial to system level power management by smoothing and limiting the PV inverter output power to some extent. This benefit is especially important to increase the PV installations with the existing grid infrastructure under a high PV penetration degree in the future. The aforementioned advantages are compromised with the energy loss due to the proposed control, allowing the optimal selection of the power control limit depending on specific mission profiles.

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