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A HYBRID MPPT-CPG POWER CONTROL CONCEPT FOR GRID CONNECTED PV INVERTER

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Abstract— With an increase of the grid-connected PV systems, an overloading in the grid may occur duringthe peak PV power production. In order to further enable more PV installations, the hybridMPPT-CPG controlstrategy of PV systems have to be limited PV power feed in to the grid , in order to provide enough power capacity. These overloading issue overcome by using MPPT-CPG controller with optimal P_{limit}.Benefits of selected P_{limit} increases utilization factor of PV inverter.

Index Terms— PV panel, DC-DC Boost converter, PV inverter, L-C-L filters,MPPT-CPG Controller, Inverter controller.

I. INTRODUCTION

Photovoltaic (PV) have a high growth rate during the last several years and are expected to play a significant role in the future power production. In the currently active grid codes for most countries, a maximum power point tracking (MPPT) is mandatory for grid-connected single-phase PV systems. With an increase of grid-connected PV system installation, the Distribution System Operators (DSO) may face challenges regarding overloading of the grid during PV peak production periods. This control strategy proposed solution can contribute to prevent overloading of the distribution grid by operating the PV inverter in a Constant Power Generation (CPG) mode (i.e., limiting the maximum feed-in power of PV systems) during the peak production[1].

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) [2] 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.

II. SYSTEM DEVELOPMENT

The single-phase two-stage grid connected PV system configuration is preferable for residential PV applications.

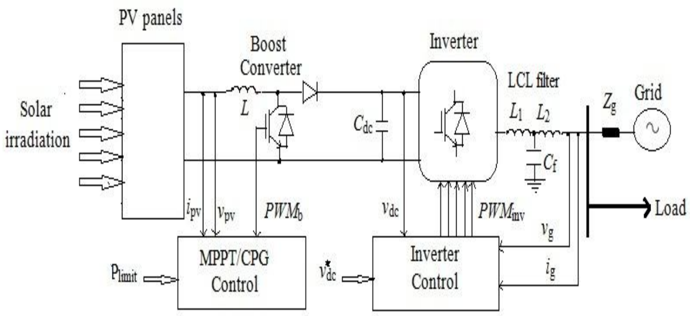
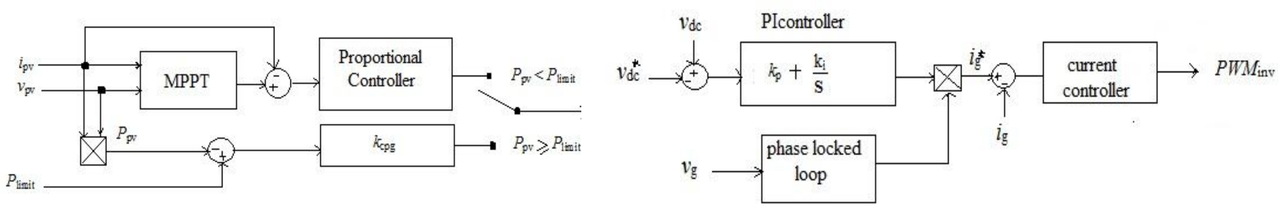


Fig.1. Schematic diagram of a two-stage single-phase grid connected PV system.



(a) (b)

Fig.2. Control diagram of a two-stage single-phase PV system with constant power generation ability by modifying MPPT control: (a) boost control diagram and (b) PV inverter control system

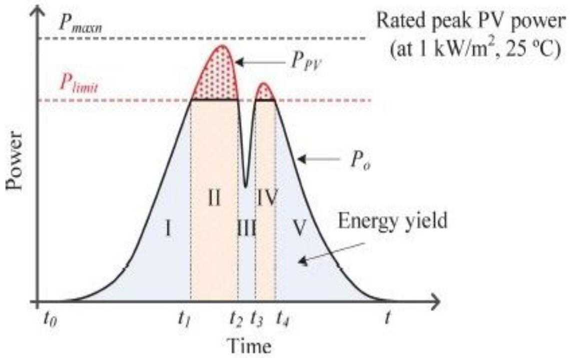


Fig.3.Operation regions (I, III, V - MPPT; II, IV - CPG) for a single-phase PV system.

The control structure two-stage single-phase PV system with the proposed control concept is shown in Fig. 2, which indicates that the hybrid control strategy is implemented in the control of the boost stage. As shown in Fig. 1, depending on the instantaneous available power of the PV panels, the actual output power of the PV panels can be expressed as

$$P_o(t) = \begin{cases} Ppv\ (t), & MPPT,\ When \quad Ppv < Plimit \\ Plimit, & CPG,\ When \quad Ppv \geq Plimit \end{cases} \quad (1)$$

Where,
$P_o(t)$ is the output power of the PV panel.
$P_{pv}(t)$ is the available maximum power of the PV panels.
Plimit is selected by taking into account the trade of thePV
inverter utilization factor, and the annual energy yield.

As the available PV power is weather-dependent, the operation modes will alter accordingly with the solar irradiance and ambient temperature. In different operation regions for a single-phase PV system during a day with the proposed control strategy [3]. Then, according to (1), it can be obtained that

$$\text{Empp} = \int_{t0}^{t} Ppv(t)dt (2)$$

$$\text{Ecpg} = \int_{t1}^{t2} Plimit\ dt + \int_{t3}^{t4} Plimit\ dt (3)$$

where
E_{mpp} is the available energy during a day with MPPT control, and Ecpgis the energy production in CPG operation
mode in regions of II and IV in Fig. 3. Hereby, the "cut-off"
energy (dotted-area) during the day can be given by,

$$\text{Eess} = \int_{t1}^{t2} Ppv(t)\ dt + \int_{t3}^{t4} Ppv(t)\ dt - \text{Ecpg} \quad (4)$$

which can be adopted as a trade-off factor to determine the power limit Plimit .

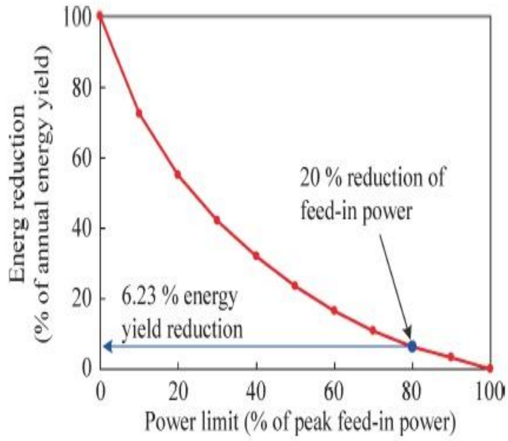


Fig.4. Energy reduction due to the limitation of maximum feed-in powerfrom a 3-kW grid-connected PV system using yearly real-field data.

According to Figs. 1 and 2, and (1), the operation principleof the proposed hybrid MPPT-CPG control can be described as follows. When $P_{PV}(t) \geq P_{limit}$, 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., *Po* (*t*) = *P*limit). When $P_{PV}(t) < P_{limit}$, the system maximizes the output power with an MPPT control, and thus the CPG control is deactivated [1].
The implementation of the hybrid control concept requires an
appropriate power limit (Plimit) as shown in Fig. 2. To quantitatively find the optimal power limit, a PV inverter utilization factor (in hours) is defined as

$$\gamma = \frac{E}{Pn} (5)$$

Where,
Eis the annual energy production
Pnis the rated maximum power of the PV inverter. Equation (5) indicates how many equivalent hours the system operates at the maximum rated power through a year.With the proposed MPPT-CPG control, i.e. Pn= Plimit, a larger value of γimplies a relative lower cost of the PV inverters, as the ratings are reduced.
The selection of Plimitshould be compromised with the energy loss defined in (4). Fig. 4 presents the dependency of energy reduction on Plimitfor a 3-kW PV system operating under a specific yearly mission profile. The energy loss is increased with the reduced value of Plimit. For example, a 20% reduction of the maximum feed-in power will result in a 6.23% reduction of the annual energy production. Correspondingly, the PV inverter utilization factor is increased by 17% ($i.e, \frac{1-0.0623}{0.8} - 1$)
Further trade-off design factors, such as the impacton the lifetime of PV inverters and the cost-of-energy ofthe PV system.

III. SIMULATION AND RESULTS

Simulations of a 3-kW two-stage single-phase PVsystem are carried out referring to Fig. 1. The parameters of the system are listed in Table I. The P&O MPPT control method is adopted in the MPPT operation mode . A proportional resonant controller is used in the current control loop for power quality consideration. In both operation modes, the dc-link voltage is regulated within 450 V to ensure the power injection, and the proposed power control is adopted [4].

Firstly, the single-phase PV system with the proposed hybrid MPPT-CPG control is tested under step-changes of solar irradiance at a constant ambient temperature. It can be noted that, when the maximum power exceeds the limitation (80% of nominal power according to Fig. 4), the CPG control is activated and thus constant output power is achieved. Once the PV power goes below the limit, the system resumes MPPT operation mode[5]. Then, the maximum power from the PV strings are fed into the grid. It demonstrates the effectiveness of the hybrid control on limiting and smoothing the feed-in power and on improving the utilization factor of the PV inverter. It should be noted that further efforts could be devoted to improving the dynamics during the transitions from MPPT mode to CPG mode or vice versa.

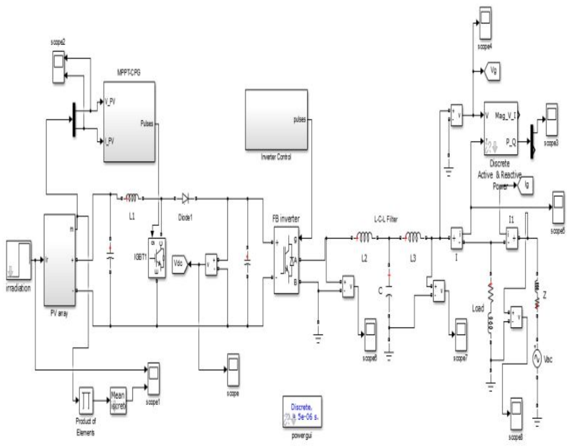


Fig.5. Simulink model of two-stage single-phase grid connected PV system.

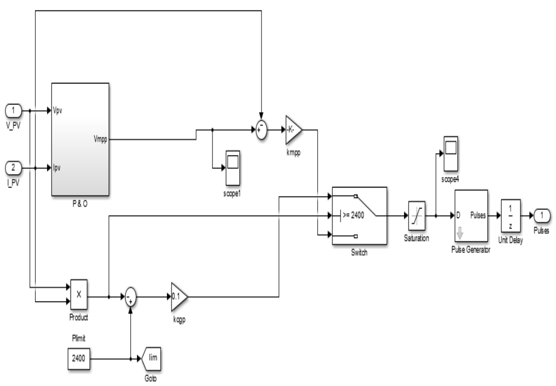


Fig.6. Simulink model of Hybrid MPPT-CPG Controller.

TABLE I
PARAMETERS OF THE 3 kW TWO-STAGE SINGLE-PHASE PV SYSTEM

Parameter	Value
PV panels rated power	P_n= 3000 W
Boost converter inductor	L = 8 mH
DC-link capacitor	C_{dc} = 2200 μF
LCL-filter	L_1 = 21 mH, L_2 = 32 mH, C_f= 4.7 μF
Switching frequencies for boost stage	f_{boost} = 10kHz
Carrier frequency Inverter	f_{inv} =1080 Hz
Grid nominal voltage (RMS)	V_g = 230 V
Grid nominal frequency	ω_0= $2\pi \times 50$ rad/s

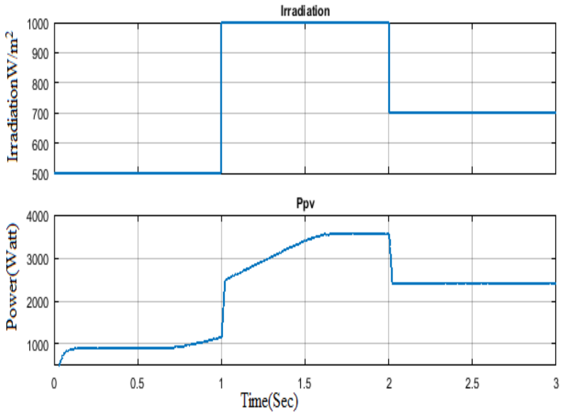


Fig.7. Simulation result of voltage based MPPT controller at step changing irradiation.

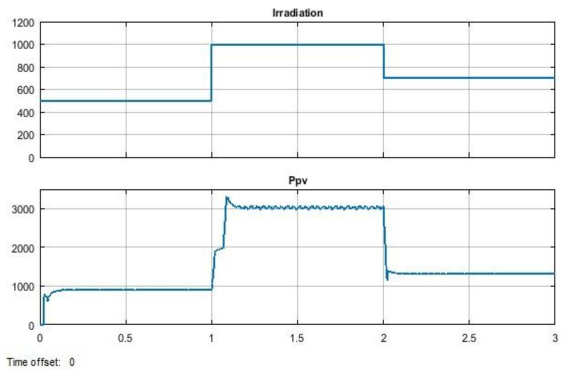


Fig.8.Simulation result Hybrid MPPT-CPG controller at step changing irradiation.

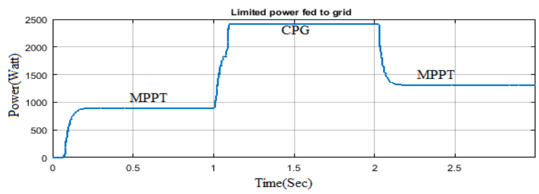


Fig.9. Power Limit 2400W.

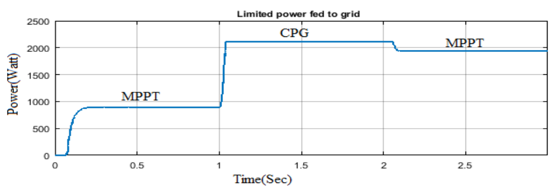


Fig.10. Power Limit 2100W

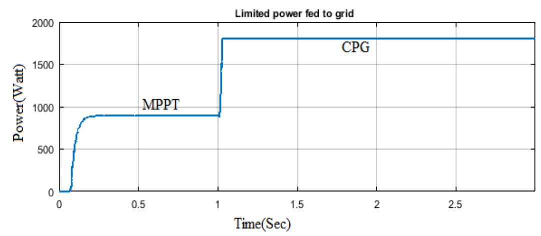


Fig.11. Power Limit 1800W

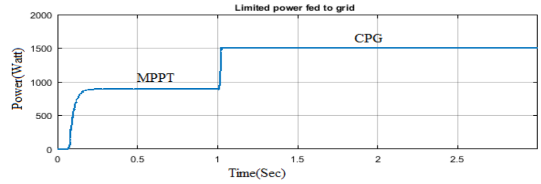


Fig.12. Power Limit 1500W

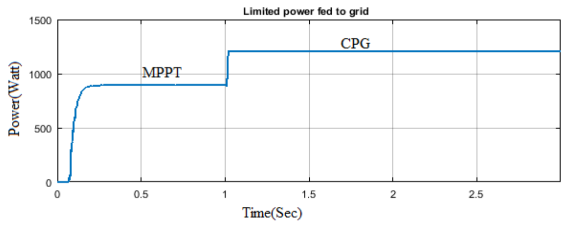


Fig.13. Power Limit 1200W

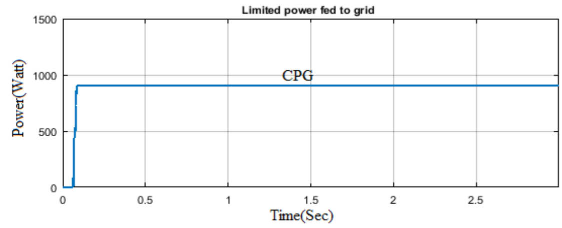


Fig.14. Power Limit 900W

IV. ANALYTICAL SOLLUTION

For 80% Power limit,

Eess =Empp – Ecpg = 0.9kWsec ………..(1)

For 70% Power limit,

Eess = Empp– Ecpg = 1.35kWsec ……...(2)

For 60% Power limit,

Eess = Empp – Ecpg = 2kWsec ……….(3)

For 50% Power limit,

Eess = Empp – Ecpg = 3.05kWsec ………(4)

For 40% Power limit,

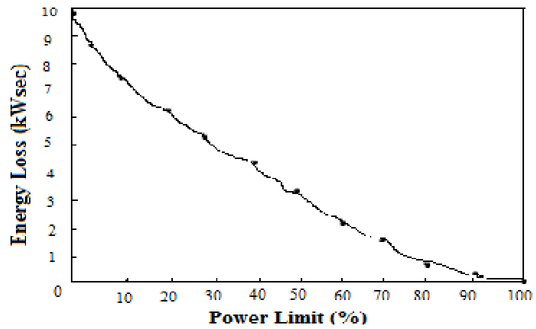
Eess = Empp – Ecpg = 4.25kWsec ………(5)

For 30% Power limit,

Eess = Empp – Ecpg = 5.45kWsec ………(6)

TABLE II

Plimit (%)	Energy loss (kW sec)
100	0.0023
90	0.12
80	0.9
70	1.35
60	2
50	3.05
40	4.25
30	5.45
20	6.08
10	7.2



CONCLUISION

As in the recent years , high growth rate of the grid-connected PV systems, it is expected that more intermittent (unnecessary) power will be injected to the grid, which may rise a problem of an overloading may occur during the peak power production .
To overcome above problem , hybrid MPPT- CPG control concept has been explored . For CPG control concept optimal Plimit of 80% is selected as it increases utilization factor by 17% and 6.23% energy yield reduction subsequently reduces cost of energy .

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