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Grid-Connected Two PV System with Synergetic MPPT Control

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***Abstract*—Photovoltaic (PV) systems are one of the sources of interesting energy, not only renewable, but as inexhaustible and non-polluting. Owing to this, the present work deals with modeling and simulation study of two small photovoltaic power plants grid connected system equipped by two maximum power point tracking (MPPT) Controllers synergetic control (SC). To check the performance of proposed scheme control, several simulations test were carried under different weather conditions.**

***Keywords*— Photovoltaic system, Modeling, Synergetic control, Grid connected PV, Matlab/Simulink, MPPT.**

I. INTRODUCTION

Over the most recent couple of many years, expanded interest for power has made the quest for the utilization of environmentally friendly power sources progressively important, drawing serious areas of strength for in the broadening of force age plants. Also, taking into account the rising revenue in spotless and manageable energy and the decrease of the effect on the climate, the utilization of sustainable power sources has been conspicuous, primarily in light of the fact that these energy sources are the primary competitors to supplant contaminating fossil-based energy frameworks [1]. Photovoltaic (PV) energy has a quickly developing yearly rate and is rapidly turning into a significant piece of the energy balance in many districts and power frameworks[2]. The limits of PV energy system, for example, the low productivity and the non-linearity of the result qualities, make it important to get a MPP activity. Minor departure from sunlight-based irradiance levels, surrounding temperatures and residue amassing on the outer layer of the PV board influence the result of the PV system [3]

The efficiency of electric power generation is quite poor, especially in low-irradiation situations, and the amount of electricity produced by solar arrays varies constantly with the weather, which are the two main issues that plague all PV systems. Under these varying weather circumstances, load mismatch prevents the load from receiving the greatest amount of power[4]. The so-called maximum power point tracking (MPPT) problem is this difficulty. For tracking the maximum power point, numerous strategies have been put out recently. The use of fractional open-circuit voltage and short-circuit current techniques offer a quick and efficient means of obtaining the most power. To measure the open-circuit voltage or short-circuit current, they must periodically disconnect or short-circuit the PV modules.

Kolesnikov introduced the synergetic control (SC) theory in broad terms[5]. Its use for a single boost converter was introduced in [6], and various practical considerations with relation to simulations and real hardware were covered in [6], [7].The papers contain the following order: The studied system is presented in Section II. In Section III Learn about design of synergetic MPPT controller. Numerical simulations under varying climate parameters are given in Section IV. Finally, some conclusions in Section V.

II. PRESENTATION OF THE STUDIED SYSTEM

In this research two PV systems in two different places are connected to same grid, A common block diagram of the two systems is presented in Fig.1, In both systems the PV array is connected to the DC-DC converter, they share the same three-phase inverter and they are connected to the grid through it. With total maximum power 100kW of each PV system.

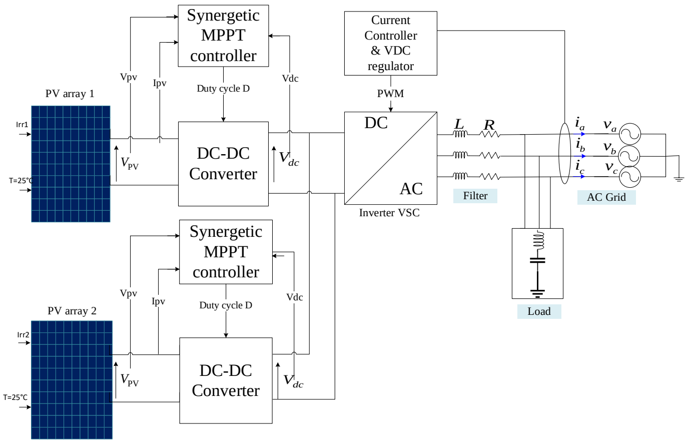

Fig1 Block diagram of the studied system with two parallel PV system and synergetic MPPT controllers

A. *Photovoltaic array model*

The model of the photovoltaic board depends on the one-diode identical circuit itemized in our different distributions[8]. This model purposes as info factors the sun-oriented radiation G, the encompassing temperature T and the module voltage V_M to work out the module current I_M. It is viewed as that all boards are indistinguishable and are dependent upon similar meteorological circumstances. The PV modules utilized in the recreation area of type SunPower SPR-305-WHT and Kyocera KD205GX-LP.

To model the PV Panel, established researchers offer a few models. The single diode model is the old style one depicted in writing. The same circuit (**fig.2**) comprises of current source to show the episode iridescent transition, a diode for cell polarization peculiarities, an equal obstruction because of spillage current and a series opposition addressing different contacts[3].

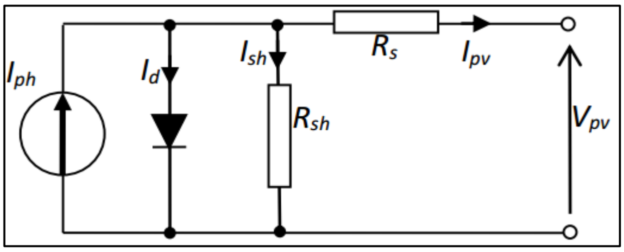

Fig 2 *Equivalent circuit of PV array*

Consequently, the nonlinear characteristics of PV cell can be represented by following equation:

$$I_{pv} = I_{ph} - I_0\left[\exp\left(\frac{q(V_{pv}+R_sI_{pv})}{N_snk_bT}\right)-1\right]-\frac{V_{pv}+R_sI_{pv}}{R_{sh}} \qquad (1)$$

$$I_{ph} = G/1000(I_{sc}+K_i(T-Tr)) \qquad (2)$$

$$I_0 = I_{rr}\left(\frac{T}{T_r}\right)^3\exp\left(\left[\frac{qE_g}{k_bn}\right]\times\left[\left(\frac{1}{T_r}\right)-\left(\frac{1}{T}\right)\right]\right) \qquad (3)$$

An ideal PV cell Rs≈0 and Rsh ≈ +OO
The equation (1) becomes:

$$I_{pv} = I_{ph} - I_d = I_{ph} - I_0\left[\exp\left(\frac{qV_{pv}}{N_snk_bT}\right)-1\right] \qquad (4)$$

Where I_{pv} is the output current (A), V_{pv} the voltage (V), I_0 is reverse saturation current, q the electronic charge, k_b is Boltzmann’s constant, T is ambient temperature in Kelvin, T_r is reference temperature, I_{rr} is the saturation current at the reference temperature, I_{sc} is the short-circuit current of PV cell under standard conditions, E_g is the energy of the band gap for silicon, n is the P-N junction’s idealist factor, Ki is the short-circuit current temperature coefficient, G is solar irradiance (W/m²).

B. *DC-DC converter model*

The DC-DC converter is "step-up" (boost) type in order to increase the PV array voltage to a level, which ensures correct operation of the inverter. The circuit is presented in fig.6, state equation of voltage results in the Eq. (5).

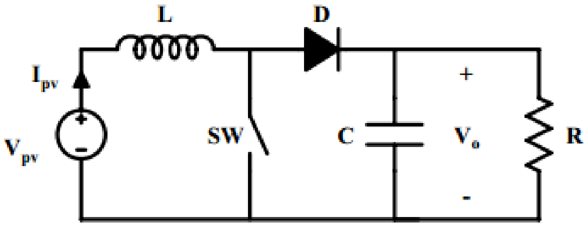

Fig 3 *DC-DC Boost converter*

$$\begin{cases}\dfrac{di_L}{dt} = \dfrac{V_{pv}-V_0}{L}+\dfrac{V_0}{L}u \\ \dfrac{dV_0}{dt} = \left(-\dfrac{V_0}{RC_2}+\dfrac{i_L}{C_2}\right)-\dfrac{i_L}{C_2}u\end{cases} \qquad (5)$$

Where V_O is the load voltage and and i_L is the current across the inductor. The output voltage of the boost converter V_O can be expressed in function of the input voltage V_{pv} and its duty cycle d:

$$\frac{V_0}{V_{pv}} = \frac{1}{1-d} \qquad (6)$$

C. *Grid-tied inverter model*

A three-phase grid-tied inverter is part of the system that was first studied. The Voltage Source Converter (VSC) inverter controls current from the grid side. An inductive filter (see fig.1) is what connects the VSC to the grid and is required for current filtering. Based on symmetric sinusoidal PWM, the control is implemented. The formulas in the three-phase inverter model are used to calculate the voltages on the alternative current sides, V_{s1n}, V_{s2n}, and V_{s3n}.[9]

$$\begin{aligned} V_{s1n} &= \tfrac{2}{3}.\gamma_1.V_0 - \tfrac{1}{3}.\gamma_2 - \tfrac{1}{3}.\gamma_3.V_0 \\ V_{s2n} &= -\tfrac{2}{3}.\gamma_1.V_0 + \tfrac{1}{3}.\gamma_2 - \tfrac{1}{3}.\gamma_3.V_0 \\ V_{s3n} &= -\tfrac{2}{3}.\gamma_1.V_0 - \tfrac{1}{3}.\gamma_2 + \tfrac{1}{3}.\gamma_3.V_0 \end{aligned} \qquad (7)$$

Where γ_i ($i \in [3,1]$) are the inverter branches states and $V_0=0.5V_{DC}$ is the inverter input DC voltage.

III. DESIGN OF SYNERGETIC MPPT CONTROLLER

The synergetic MPPT control idea is introduced in this paper (Fig 4):

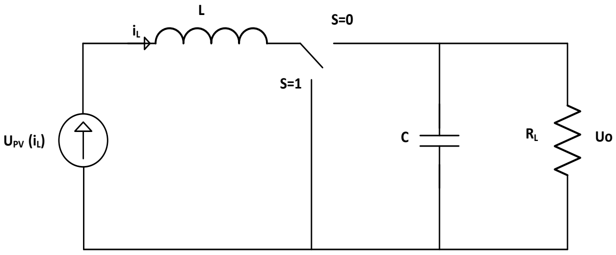

Fig 4 *MPPT system circuit*

The system is written as a two-state set equation that depends on the position of the switch.

$$\frac{di_L}{dt} = -(1-D)\frac{U_0}{L} + \frac{U_{PV}}{L} \tag{8.a}$$

$$\frac{dU_0}{dt} = (1-D)\frac{i_L}{C} - \frac{U_0}{R_L C} \tag{8.b}$$

where C is the capacity, L is the inductance, R_L is the resistive load, D is the duty ratio control input ∈ [0 1]. U_0 is the output voltage and i_L is the inductor current. Note that the equivalent series resistance (ESR) of the inductor and wiring resistance are neglected in this case, so i_L is assumed equal to the PV current (I_{PV}). Eq. (8) is written in nonlinear time invariant system general form.

$$\dot{x} = f(x) + g(x)D \tag{9}$$

It is ensured that the system state will hit the manifold and consistently deliver maximum power output by choosing the manifold with PPV/IPV = 0.

$$\boldsymbol{\frac{\partial P_{PV}}{\partial I_{PV}} = \frac{\partial I^2{}_{PV} R_{pv}}{\partial I_{PV}} = 2I_{PV}R_{PV} + I^2{}_{PV}\frac{\partial R_{PV}}{\partial I_{PV}} = I_{PV}\left(2R_{PV} + I_{PV}\frac{\partial R_{PV}}{\partial I_{PV}}\right) = 0} \tag{10}$$

Where $R_{pv}=V_{PV}/\ I_{PV}$ is the equivalent load connect to the PV, and I_{pv} the PV current which is equal to i_L in this case.

The solution of (10) is $2R_{PV} + I_{PV}\frac{\partial R_{PV}}{\partial I_{PV}} = 0$

Hence, the manifold is defined as:

$$\Psi = 2R_{PV} + I_{PV}\frac{\partial R_{PV}}{\partial I_{PV}} \tag{11}$$

Then the desired dynamic evolution of the macro-variable is expressed as:

$$T_S\left(\frac{d\Psi}{\mathrm{dx}}\right) + \Psi = 0\ ;\ T_s > 0 \tag{12}$$

Where

$$\frac{d\Psi}{\mathrm{dt}} = \left(\frac{d\Psi}{\mathrm{dx}}\right)\left(\frac{\mathrm{dx}}{\mathrm{dt}}\right) \tag{13}$$

The substitution of Ψ′ from Eq. (13) into the functional equation (12) yields to

$$T_S\left\{\left(\frac{d\Psi}{\mathrm{dx}_1}\right)\left(f(x) + g(x)D(t)\right)\right\} + \Psi = 0$$

$$\left(\frac{\partial\Psi}{\partial x_1}\right)\left(\left(\frac{U_{PV}-U_0}{L}\right) + \left(\frac{U_0}{L}\right)D(t)\right) = -\frac{\Psi}{T_S} \tag{14}$$

$$D(t) = 1 - \left(\frac{\Psi L}{U_0 T_S \frac{\partial\Psi}{\partial x_1}}\right) - \left(\frac{U_{pv}}{U_0}\right) \tag{15}$$

The time derivative of Ψ can be written as:

$$\frac{\partial\Psi}{\partial x_1} = 3\frac{\partial R_{PV}}{\partial i_L} + i_L\frac{\partial^2 R_{PV}}{\partial {i_L}^2} \tag{16}$$

The synergetic control signal is defined as:

$$D(t) = 1 - \left(\frac{\Psi L}{U_0 T_S\left(3\frac{\partial R_{PV}}{\partial i_L} + i_L\frac{\partial^2 R_{PV}}{\partial {i_L}^2}\right)}\right) - \left(\frac{U_{pv}}{U_0}\right) \tag{17}$$

For the system's state variables, the Lyapunov function is a positive scalar function. The goal is to select a scalar function that will draw the controlled variable to its reference value. The Lyapunov function is defined as follows:

$$V_L = \frac{1}{2}\Psi^2 \tag{18}$$

The derivate of V_L is:

$$\frac{dV_L}{dt} = \Psi\left(\frac{d\Psi}{dt}\right) = \Psi\left[\left(-\frac{1}{T_S}\right)\Psi\right] \tag{19}$$

Consequently, we have:

$$\frac{dV_L}{dt} = \left(-\frac{1}{T_S}\right)\Psi^2 \tag{20}$$

IV. SIMULATION RESULTS

In this section, the simulation results of the studied system are presented.

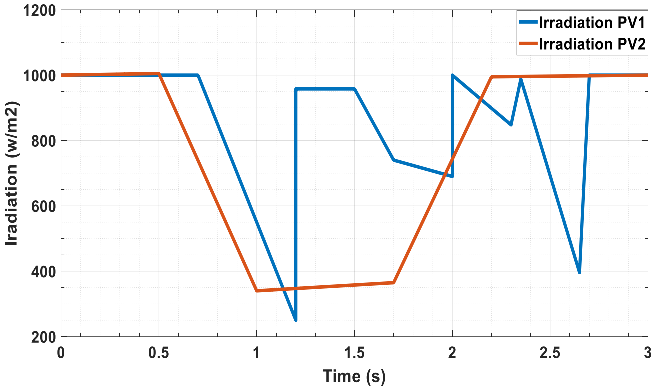

Fig 5 *Irradiance profile for each PV array*

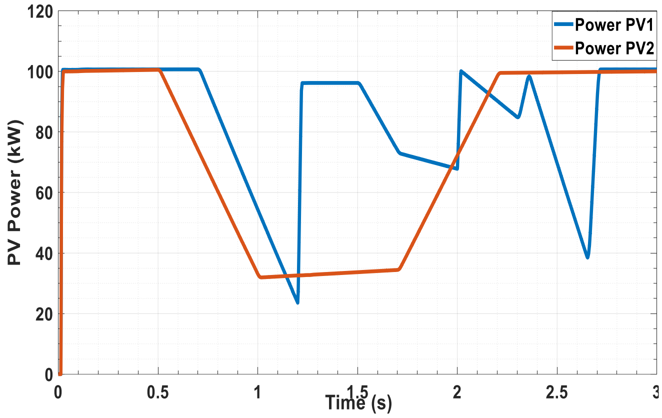

Fig 6 *Power of synergetic MPPT with irradiation changes of each PV array.*

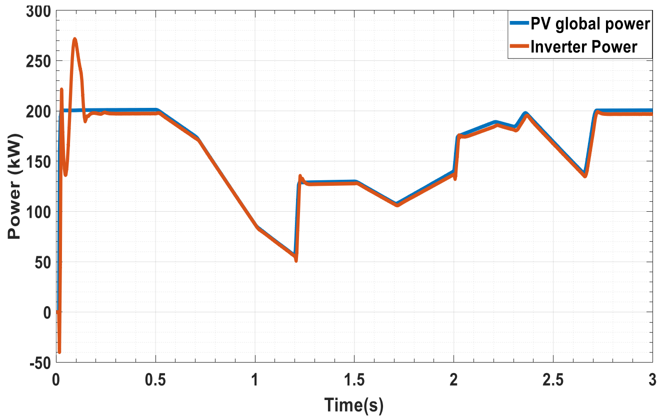

Fig 7 *Comparison between PV global power and inverter power using synergetic MPPT*

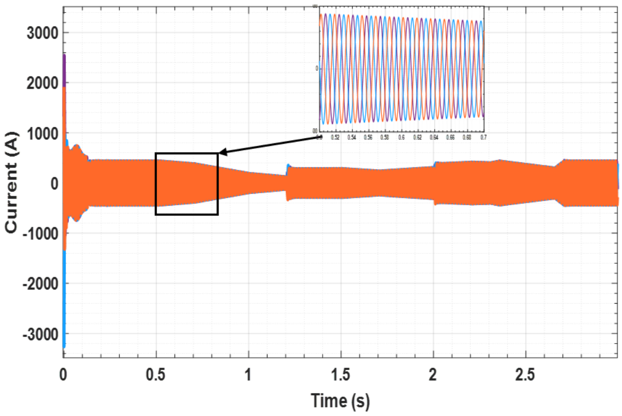

Fig 8 Three-phase *current with irradiations changes*

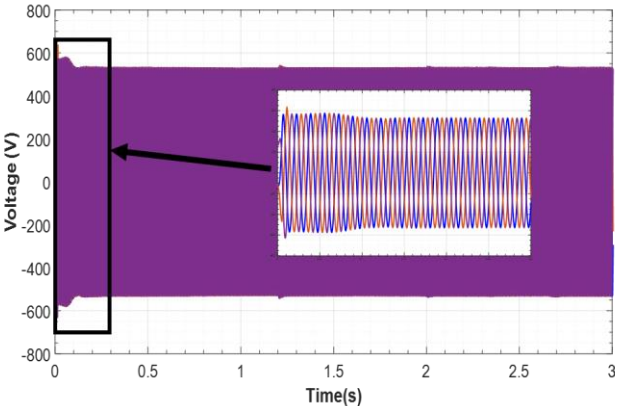

Fig 9 *Three-phase voltage with irradiations changes*

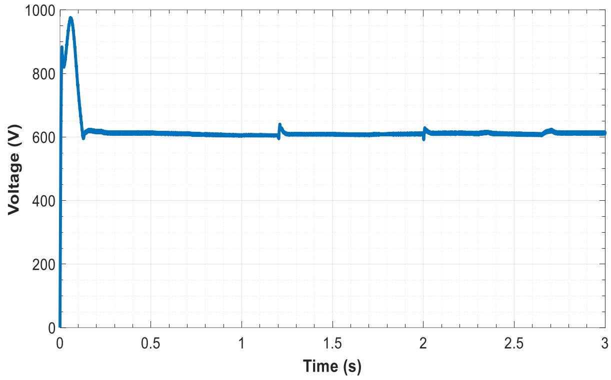

Fig 10 *DC boost converter voltage*

The results from Figures 5–10 demonstrate the a good stability in steady state The study of robustness for synergetic controllers showed that controller reach the MPP verry fast regardless of the irradiance conditions of the PV system.

V. CONCLUSION

In this paper an efficient MPPT control strategy based on the synergetic control theory has been tried with grid connected two PV system. This system is mainly composed of two solar array, DC/DC boost converters, synergetic MPPT controllers and a three phases inverter connected to a small grid. The stability of the closed-loop system is guaranteed using the Lyapunov synthesis.

The used controller has successfully tracked the maximum power point photovoltaic systems under different solar irradiances. From simulation results, it can be concluding: That synergetic control can increase the robustness of the scheme control.

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