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Power Generation Method from Adaptive Control Power Point Tracking System

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Abstract:

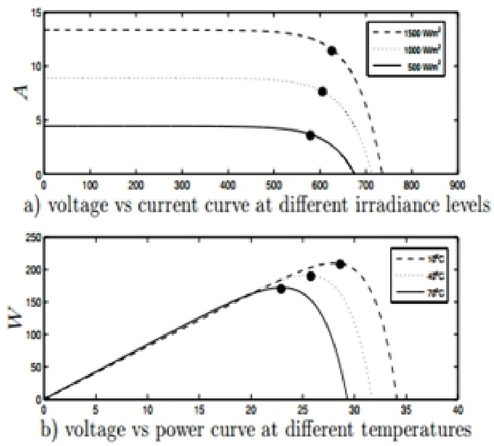
An adaptive control scheme for maximum power point tracking of a single-phase single-stage photovoltaic system connected to the grid is presented. The maximum power point depends on temperature and solar irradiance, ambient conditions that are time-varying and difficult to measure. Two solutions are presented. Each solution derive an estimator that approximate three different parameters. These parameters are functions of solar irradiance and temperature. In this manner, we eliminate the necessity of climatic sensors. The first solution, uses an adaptive estimator that is able to estimate constant parameters, and the second one uses a sliding mode estimator that is capable of estimate time-varying parameters. A complete analysis was done taking into account the nonlinearities showed by the closed-loop system. The Lyapunov redesign technique was used to derive a controller that gives globally asymptotically stable trajectories of the closed-loop system. Computer simulations are presented to compare the performance of both estimators and also to show the good performance of the controller.the power conversion system. The original transfer function of the power conversion system has time-varying parameters, and its step response contains oscillatory transients that vanish slowly. Usingthe Lyapunov approach, an adaption law of the controller is derived for the MRAC system to eliminate the under damped modesin power conversion.

Index Terms:

Maximum power point tracking (MPPT), model reference adaptive control (MRAC), photovoltaic system, ripple correlation control (RCC).

I. INTRODUCTION:

New policies and regulations have been developed to face the growing energy needs and climate change. These facts have stimulated the interest on renewable energy sources. Solar photovoltaic is one of them. Photovoltaic systems (PVS) converts sunlight directly into electricity by means of a semi conductive process. Grid-connected PVS usually consists of a photovoltaic panel or array and a power conditioning system (PCS). The output power of a photovoltaic array is function of irradiance and temperature. To increase the efficiency of the overall system, PVS always needs to work in its maximum power point, to deliver the maximum amount of energyHence, an algorithm that can follow these power changes is needed. This is the maximum power point tracking (MPPT) algorithm.



MPP of a typical PV array for different environmental conditions. a) Voltage vs. current curve at T = 25oC and different irradiance values. b) Voltage vs. power curve at G = 1000W/m2 and different temp. values.

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There are several MPPT algorithms like perturb and observe, incremental conductance, extremum-seeking among others. They compute the value of the voltage corresponding to the maximum power point. This voltage is then used as a reference value in the controller-Previous works on MPPT control of PVS were done by splitting the problem in two parts: a control capable of tracking the MPP and a control capable of deliver a sinusoidal current in phase with the grid voltage. Solutions like feedback linearization and sliding mode techniques were applied to the first part.

parameters that depends on temperature are known. In this paper, we are presenting two solutions that uses an adaptive scheme control that is capable of achieving MPP tracking for changing environmental conditions and deliver unity power factor current to the grid. In the first solution, an adaptive estimator is designed, and in the second one, a sliding mode estimator capable of estimate time-varying parameters. Both, estimate parameters that depends on irradiance and temperature.

No assumption about known parameters was made and global stability is proved in both cases, taking into account the nonlinear model and the estimates of the parameters. The main contribution consists in the full analysis —nonlinear model, controller and estimators— of the system, increasing of the robustness and elimination of the necessity of irradiance and temperature sensors with these estimators

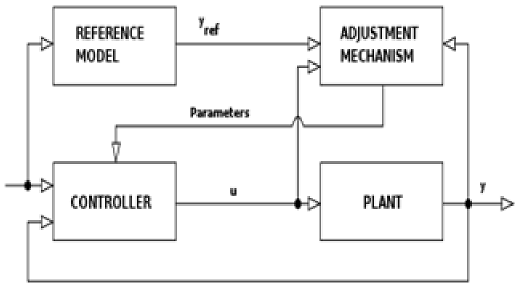
Adaptive control:

Adaptive control is the control method used by a controller which must adapt to a controlled system with parameters which vary, or are initially uncertain. For example, as an aircraft flies, its mass will slowly decrease as a result of fuel consumption; a control law is needed that adapts itself to such changing conditions.

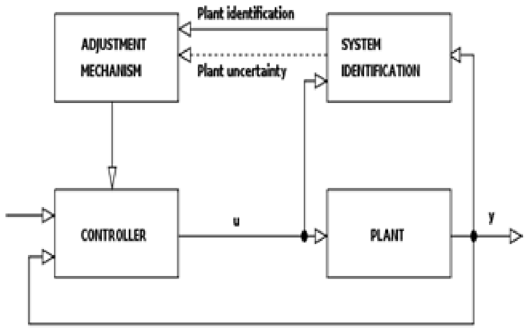
Adaptive control is different fromrobust control in that it does not need a priori information about the bounds on these uncertain or time-varying parameters; robust control guarantees that if the changes are within given bounds the control law need not be changed, while adaptive control is concerned with control law changing themselves.

II.PARAMETER ESTIMATION:

The foundation of adaptive control is parameter estimation. Common methods of estimation include recursive least squares and gradient descent. Both of these methods provide update laws which are used to modify estimates in real time (i.e., as the system operates). Lyapunov stability is used to derive these update laws and show convergence criterion (typically persistent excitation). Projection (mathematics) and normalization are commonly used to improve the robustness of estimation algorithms. It is also called adjustable control.



MODEL REFERENCE ADAPTIVE CONTROL (MRAC)



MODEL IDENTIFICATION ADAPTIVE CONTROL (MIAC)

PROBLEM FORMULATION AND MATHEMATICAL MODEL OF THE PHOTOVOLTAIC SYSTEM:

Consists in a PV array of solar cells and a DC/AC PCS. The states of the system are given by the capacitor voltage (x1) and the inductor current (x2). The PCS is a full-bridge inverter driven by a bipolar PWM scheme. The PWM gives two discrete complementary signals s and $\bar{s}$ which turn on and off the four switches in the PCS. The PWM block is fed by the control signal u[−1,1].

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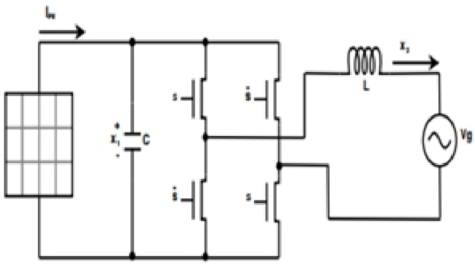

A. Mathematical model. The PV array is composed by PV cells arranged in series and parallel. The PV cell model used in this work is the single-diode model with no resistors. In and the authors present some models and give explicit relations to get the electric characteristics which are functions of irradiance and temperature. A comparative analysis was made in and it is shown that all models have no significant differences for MPPT purposes.

The I–V characteristic curve of a PV array with identical cells is given by:

I = Iph(G)Np − Io(T)NpexpqVnNskBT − 1

where Iph is the photocurrent, that depends on irradiance G, Io is the saturation current, that depends on temperature T, q is the absolute value of electron's charge, n is the quality factor of the diode, Np is the number of cells connected in parallel, Ns is the number of cells connected in series, kB is Boltzmann's constant and T is the temperature of the P-N junction. V is the capacitor voltage x1. This equation can be written in a simpler way:

I(x1) = c1 − c2e c3x1

where c1 is function of irradiance and temperature and c2 and c3 are functions of temperature. The model of the whole system is given by:

x˙ = f(t, x) + G(t, x)u

C and L are known values of the capacitor and the inductor respectively, and vg the grid voltage. The signals that are measured are the states x R 2 , the voltage grid vg R and the PV array current I R, which is a common practice in this type of circuits. u is the control signal composed by the terms:

u = un + w + δ(t, x) δ(t, x) is an uncertain term that satisfies the matching condition (i.e. it enters at the same point that the control signal u), w is the term that will be derived to compensate it and un is the control component that turn the nominal system globally asymptotically stable. In section IV, these components are explained in detail. The nominal system is the system without the uncertain term δ(t, x), hence: x˙ = f(t, x) + G(t, x)un (6) where f(t, x) and G(t, x) are defined in the same way that before. The main tasks that the signal control u must fulfill are:

1) To track the maximum power point of the PV array, despite of changes in the environmental variables irradiance and temperature.

2) To deliver a current in phase with the grid voltage (i.e. unity power factor). The controller needs two references to accomplish the main tasks of the system. The first reference is the voltage DC value in the capacitor

x¯1∗∈ R+ and is given by the MPPT algorithm. The second reference is the current value in the inductor x2∗, which is taken from x2∗, 2 vg (t) ¯x1∗ I∗ (¯x1∗, ci) A2

Where I∗ is the PV current evaluated at

x¯1∗ and vg is assumed to be sinusoidal with constant amplitude A and frequency

ω, vg = Asin(ωt).

The parameters ci in I∗ are unknown. Therefore, two different estimators were designed and presented here. They allow to calculate the full I∗ expression. Hence, the second reference becomes:

xˆ2∗, 2 vg (t) ¯x1∗ ˆI∗ (¯x1∗, cˆi) A2

Where ˆ(·) indicate the estimate of (·).

III. ESTIMATORS DESIGN:

A reparametrization was made in order to be able to design the next two estimators.

the derivative of the current I is:

˙I = −c2c3x˙1e c3x1 = 1 C (ux2 − I)(θ1 − θ2I) = ΦT θ

where: θ , c1c3 c3 , Φ T , 1 C ux2 − I, −ux2I + I 2

also consider the following estimator and observer errors respectively,

˜θ = ˆθ − θ, ˜I = ˆI − I

for the next subsections. A. Adaptive estimator. An adaptive estimator capable of estimate constant parameters is designed in this subsection. The estimator is given by: ˙ˆI = −λ(ˆI − I) + ΦT ˆθ (11) ˙ˆθ = −ΓΦ(ˆI − I) where λ > 0 and Γ is a square diagonal matrix 2 x 2 with positive values. Let us assume the following: Assumption 1-A. The parameters vector θ is constant, i.e. ˙θ = 0 Lemma 1. Consider the observer and the estimator, satisfying assumption 1-A, then the product Φ T ˜θ converges to zero. Proof. Let's first rewrite the estimation errors as:

˜I → 0 as t → ∞

Therefore,

that Φ T ˜θ → 0 as t → ∞ Furthermore, if the regressor Φ (t) satisfies the persistent excitation condition

Z t+To t Φ (τ) ΦT (τ) dτ ≥ αIm∀ t ≥ to

whereIm is the identity matrix and to, To and α are positive constants, then we can in addition conclude that ˜θ → 0 as t → ∞ . B. Sliding mode estimator. a new framework for nonlinear systems timevarying parameter estimation using sliding mode techniques was proposed. The following notation is used in this subsection:

|x T |G = (|x1|, |x2|, ... |xn|) diag (A) is the column vector whose elements are the diagonal elements of a given square diagonal matrix A. The function sign (·):

R n → R n is defined as sign(x T) = (sign(x1), sign(x2), ...sign(xn))

With x T = (x1, x2, ... xn) and sign (xi)
Assumption 1-B. The derivatives of the parameters vector θ are bounded and these bounds are known: ˙θi(t) ≤ μθi where μθi are known positive numbers and i = 1, 2. In order to design the time-varying parameter estimator consider the following adaptive observer for the current I:
˙ˆI = vI + ΦT ˆθ
wherevI = −KI sign(ˆI − I) (20) thus ˜˙ I = vI + ΦT ˜θ. For KI sufficiently chosen large
KI > |Φ T ˜θ|
and assuming that ˆθ is bounded (the proof will be shown later) then a sliding mode regime occurs on the manifold ˜I = 0 and 0 = vIeq + ΦT ˜θ then vIeq = −Φ T ˜θ

The following approximation is used (see the work of Utkin
vIeq = 1 1 + τsvI
where s is the Laplace operator and τ 0 is a positive constant. Hence ˜θ = −(ΦΦT) −1ΦvIeq and finally ˙ˆθ = −Kθsign(˜θ)
Let us choose the gain matrix for the estimator such that: diag(Kθ)i > μθi
Lemma 2. Consider the following Lyapunov candidate function
V = 1 2 ˜θ T ˜θ , β(˜θ)
Its time derivative is:
V˙ = ˜θ T ˜˙ θ = −|˜θ T |Gdiag(Kθ) − ˜θ T ˙θ ≤ −|˜θ T |G(diag(Kθ) − μθ)
and due to the inequality V˙ is negative-definite for ˜θ 6= 0. Therefore the estimation error ˜θ will converge to 0 in finite time. C. Persistent excitation condition. It is not necessary that the regressorΦ(t) satisfies the persistent excitation condition because the estimates are just used in the calculation of I(˜x1, ci). The only necessary condition is that the estimators approximate the current I by means of its dynamics: ˙ˆI(˜I, Φ T ˆθ) ˙I(x1, ci) and it is satisfied if:
Φ T ˆθ Φ T θ IV.

CONTROLLER DESIGN:

In order to accomplish the control objectives, the problem has been divided in two parts:
1) To find the control portion that renders the nominal system globally asymptotically stable (GAS).
2) To find the control portion that compensates the uncertain term δ (t, x) and gives the whole system GAS. A. Controlling the nominal system. In this part of the analysis it is considered that the x2∗ reference is well known, i.e. ˜I (t) = 0. According to the idea given in the control is decomposed in two parts: one for the steady-state stage u∗n and another for the dynamic stage eun. The reference system is: x˙ ∗ = f(t, x∗) + G(t, x∗)u∗n Hence, the control component for the steady state is:

u∗n = Lx˙ 2∗ + vg(t) x1

Consider the tracking errors and the variable control:
e = x − x∗, eun = un − u∗n e˙ = ˙x − x˙ ∗ = l(x1) −l∗ C 0 + " − e2u∗n C − (e2+x2∗) eun

C e1u∗n L + (e1+x1∗)eun L #

Let us propose the Lyapunov candidate function Vn = C 2 e 2 1 + L 2 e 2 2

Its time derivative is:

V˙ n = Ce1e˙1 + Le2e˙2 = e1(l − l∗) − e1[e2u∗n + (e2 + x2∗)eun] +e2[e1u∗n + (e1 + x1∗)eun] = −c2e1(e c3x1 − e c3x1∗) − eun(e1x2∗ − e2x1∗) Consider the controller for the error dynamics of the nominal system: eun

,

e1x2∗ − e2x1∗ (31) thus V˙ n = −c2e1(e c3x1 − e c3x1∗) − (e1x2∗ − e2x1∗) 2

From the fact that the first term of the right side of is < 0 ∀ e1 6= 0, the nominal system is GAS. B. Controlling the whole system.

The control part of the nominal system was established These equations are functions of

x˙ 2∗ and x2∗, and these values are not exactly known. Therefore, the control for the whole system is
u = u∗n (x2∗) + eun (x2∗) + ∆u∗ + ∆eu = u∗n + eun + δ (t, x) (33) where δ (t, x) ,

∆u∗ + ∆eu = L∆ ˙x2∗ x1∗ + e1∆x2

is the uncertain term, and ∆ ˙x2∗, ∆x2∗ are the perturbations due to the transients in the observer, i.e. ˜l 6= 0. In order to derive the controller for the whole system the next assumption is needed. Assumption

2. The uncertain term is bounded and known, i.e. ||δ(t, x)||2 < ξ where ξ is a known positive number. Since this uncertain term satisfies the matching condition, the Lyapunov redesign technique is used to derive a term w that will compensate it.

u = un + δ(t, x) + w

Where un=u∗n+eun
The closed-loop system becomes

x˙ = f(t, x) + G(t, x)un + G(t, x)[w + δ(t, x)]

and e˙ = f(t, x) + G(t, x)un − x˙ ∗ + G(t, x)[w + δ(t, x)] Consider the Lyapunov candidate function for the whole system:

V = C 2 e 2 1 + L 2 e 2 2 + β

Where β was defined for each estimatorLet us omit the arguments of the functions. The time derivative of V is:

V˙ = ∂V ∂e {f + Gun − x˙ ∗} + ∂V ∂e {G[w + δ]} + β˙ = V˙ n + β˙ + ∂V ∂e Gw + ∂V ∂e Gδ We can derive the w term as follows: ∂V ∂e Gw + ∂V ∂e Gδ ≤ ∂V ∂e Gw + ξ ∂V ∂e G 2 and now we can choose:
w, −ξ ∂V ∂e G || ∂V ∂e G||2 = −ξ −e1x2 + e2x1 | − e1x2 + e2x1| Theorem 1. Consider the system given by (3)-(4

Satisfying assumptions 1-A|1-B and 2, then, the whole system is globally asymptotically stable. Proof.

∂V ∂e GW + ∂V ∂e Gδ ≤ −ξ ∂V ∂e G 2 + ξ ∂V ∂e G 2 = V˙ is negative definite and the whole system is GAS with the controller given by un + w. V.

SIMULATION RESULTS:

Numerical simulations were made in the Simulink/Matlab platform to verify the performance of the estimators and the controller.

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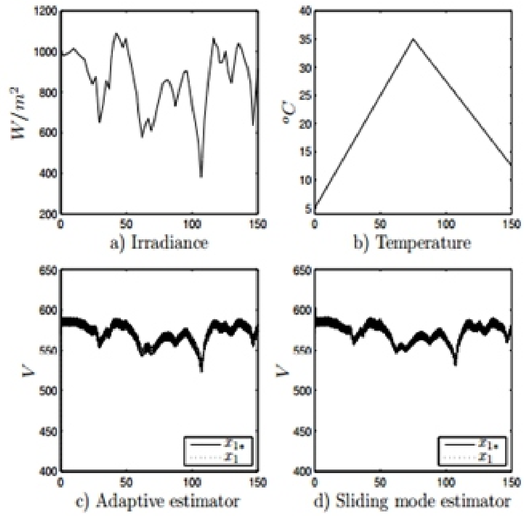
Two scenarios were simulated. In the first one, realistic variations were applied to the irradiance signal and a ramp to the temperature signal, for both estimators. Graphs a) and b) in figure show these variations. The adaptive estimator is not able to track step changes since it was designed for constant parameters, and the second scenario was simulated just for the sliding mode estimator. It consists in step changes in both variables, irradiance and temperature. Its values were changed by 50%. This is one of the worst conditions for MPPT in PVS, and because of this, a standard simulation scenario. For both simulations, the initial conditions in the plant were zero and in the estimators 1x10−5 .the results for the first scenario. The graphs c) and d) in figure 3 show the first reference x1, given by the MPPT algorithm, and the capacitor voltage0.



x1 for both estimators. The performance of the controller is very good in both cases. The results are pretty similar. The maximum power point current I and the maximum power point current estimated ˆI are shown in graphs a) and b) in figure 4. The adaptive estimator shows bigger deviations from I. Graphs c) and d) in figure 4 show the output power in both estimators. The results are similar. This is the maximum power that the PVS can deliver with the irradiance and temperature given. Figure 5 shows the results for the second scenario. The step changes in irradiance and temperature for the sliding mode estimator are shown in graphs a) and b) in figure 5. The values were changed by 50%. The graphs c), d) and e) in the same figure show that the controller and the estimator present a good performance, even under these demanding conditions.

Some noticeable ripple appears after the step variations, due not only to the variation speed but also to the variation level (50%). The output power is shown in graph e) of the same figure. It clearly follows the environmental variations.

VI. CONCLUDING REMARKS AND FUTURE RESEARCH:

Two solutions for the MPPT of PVS were presented. For the first adaptive scheme control (ASC), an adaptive estimator was designed. It is capable of estimate constant parameters. For the second ASC, a sliding mode estimator was designed. It is capable of estimate time-varying parameters.

A Lyapunov function that proves GAS of the system was derived. The analysis includes the dynamics of the estimators and the uncertainty in the second reference x2. Even when GAS was demonstrated for the system including estimators and perturbations, there is one subjectthat can enrich the analysis, it is the inclusion of the MPPT algorithm in the closed-loop system analysis.

We are currently investigating how to achieve this. Numerical simulations were made to verify the performance of the solutions. Both ASC have good performance under realistic conditions. The sliding mode ASC has the better performance. It can works well even under very demanding conditions. Acknowledgements The work of F. Jaramillo has been supported by CONACyT, Mexico and the French Embassy in Mexico. Also, the authors give thanks to Dr. R. Ortega for his contribution with the adaptive estimator.

REFERENCES:

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[1] SoerenBaekhoejKjaer, John K. Pedersen and FredeBlaabjerg, "A Review of Single-Phase Grid-Connected Inverters for Photovoltaic Modules", IEEE Transactions on Industry Applications, Vol. 41, No. 5, pp. 1292-1306, September-October 2005,

[2] YaosuoXue, Liuchen Chang, SoerenBaekhoejKjaer, JosepBordonau and Toshihisa Shimizu, "Topologies of Single-Phase Inverters for Small Distributed Power Generators: An Overview", IEEE Transactions on Power Electronics, Vol. 19, No. 5, pp. 1305-1314, September 2004,

[3] Nicola Femia, Giovanni Petrone, Giovanni Spagnuolo and Massimo Vitelli, "Optimization of Perturb and Observe Maximum Power Point Tracking Method", IEEE Transactions on Power Electronics, Vol. 20, No. 4, pp. 963-973, July 2005,

[4] T. Esram and P. L. Chapman, "Comparison of photovoltaic array maximum power point tracking techniques", IEEE Transactions on Energy Conversion, Vol. 22, No. 2, pp. 439-449, June 2007,

[5] Daniel Nahum Zmood and Donald Grahame Holmes, "Stationary Frame Current Regulation of PWM Inverters With Zero Steady-State Error", IEEE Transactions on Power Electronics, Vol. 18, No. 3, pp. 814-822, May 2003, 0 5 10 15 20 400 600 800 1000 1200
a) Irradiance W/m 2 0 5 10 15 20 20 25 30 35 40
b) Temperature o C 0 5 10 15 20 400 450 500 550 600 650
c) Capacitor voltage x1 V x1 x1 0 5 10 15 20 0 5 10
d) MPP current I A I ˆI 0 2 4 6 8 10 12 14 16 18 20 0 1000 2000 3000 4000 5000
e) Output power W Ideal M.P. Output Power Fig. 5. Step changes and results got in the numerical simulation for the sliding mode estimator.
a) Irradiance signal b) Temperature signal c) x1 and x1 signals d) Iand Iˆ signals e) Theoretical maximum power and output power

[6] Adrian V. Timbus, MihaiCiobotaru, Remus Teodorescu and FredeBlaabjerg, "Adaptive Resonant Controller for Grid-Connected Converters in Distributed Power Generation Systems", in Proceedings IEEE Applied Power Electronics Conference 2006, pp. 1601-1606.

[7] C. Meza, D. Jeltsema, J. Scherpen, D. Biel, "Passive P-Control of a Grid-Connected Photovoltaic Inverter", in Proceedings of the 17th World Congress, The International Federation of Automatic Control, Seoul, Korea, pp. 5575-5580, July 6-11, 2008

[8] S. Sanders and G. Verghese, "Lyapunov-based control for switched power converters", IEEE Transactions on Power Electronics, Vol. 7, No. 1, pp. 17-24, January 1992,

[9] C. Meza, D. Biel, D. Jeltsema and J.M.A. Scherpen, "LyapunovBased Control Scheme for Single-Phase Grid-Connected PV Central Inverters", IEEE Transactions on Control Systems Technology, Vol. 20, No. 2, pp. 520-529, March 2012,

[10] J. A. Gow, C. D. Manning, "Development of a photovoltaic array model for use in power-electronics simulation studies", IEEE Proceedings on Electric Power Applications, Vol. 146, No. 2, pp. 193-200, March 1999,

[11] Etienne Saloux, Alberto Teyssedou, MikhalSorin, "Explicit model of photovoltaic panels to determine voltages and currents at the maximum power point", Solar Energy, 85, pp. 713-722, 2011,

[12] Thomas Bennett, Ali Zilouchian, Roger Messenger, "Photovoltaic model and converter topology considerations for MPPT purposes", Solar Energy, 86, pp. 2029-2040, 2012,

[13] Jean-Jacques E. Slotine, Weiping Li, Applied Nonlinear Control, Prentice—Hall, 1991.

[14] Kumpati S. Narendra, Anuradha M. Annaswamy, Stable Adaptive Systems, Prentice—Hall, 1989.

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