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Transient Performance Improvement of MPPT Controller

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Abstract: This work presents a two level MPPT scheme in PV Systems which consists of RCC and MRAC respectively. The second introduced level aims to improve the tracking efficiency and transient performance of the overall PV system under changing weather scenario. The implementation of this two-level architecture has been done on MATLAB/SIMULINK and analysis of the result has been presented. The simulation results prove that the system was able to converge to MPP very fast using MRAC.

Keywords: Maximum Power Point Tracking (MPPT), Photovoltaic (PV), Ripple Correlation Control (RCC), Model Reference Adaptive Control (MRAC).

I. INTRODUCTION

The rapid changes occurring in the climate, calls for the improvement in the techniques that provide us with the use of renewable energy. Solar energy is a constant source of sustainable energy and to harvest it we use photovoltaic systems, these systems are environment-friendly but to maintain their efficiency, Maximum power point tracking algorithms (MPPT) are required [1]. Due to the influence of the varying environment conditions like change in irradiance or temperature, these MPPT algorithms ensure the continuous delivery of maximum power to the load. Generally, MPPT algorithms are consolidated with power electronic converter systems and deliver maximum power by controlling the duty cycle of the converter.

Different MPPT algorithms were developed and are constantly being improved [2], with the sole purpose of improving the efficiency of the PV systems. Among these algorithms, P&O is mostly used, as it is inexpensive with simple implementation but this algorithm inefficient when it comes to steady-state improvement, it tries to achieve the MPP by perturbing the operating voltage of PV array [3]. The major drawback of this algorithm is it fails under changing atmospheric conditions like change in irradiance or partial clouding condition. This method requires to constantly alter the array voltage along with trying to achieve the MPP, but it is inefficient as it compels the system to constantly oscillate about the MPP . The other commonly used algorithm is Incremental Conductance (INC) [4], this method has proven to perform well under changing atmospheric conditions, but its major drawback is, it has increased response time and has complex software and hardware requirement.

There are various other algorithms like fractional open-circuit voltage (FOVC), fuzzy logic, fractional short-circuit current, neural network, etc. as shown and compared in [5].

The photovoltaic system consists of PV array, power converters (power optimizer, module inverter/micro-inverter) which integrated with the MPPT controller [6]. As a part of this project, a DC-DC converter is used in the PV system. The MPPT algorithm is established on the principle of using the ripple current or voltage component to find power output with the knowledge of the power output vs the voltage and the current vs the voltage of the PV system

The MPPT used in this work consists of a two-level control algorithm [7]. The first level is used to achieve the maximum power in steady-state , in this level RCC is used to calculate the duty cycle , which correlates the ripple power component and the ripple voltage or current component of the power electronic system used in the PV system. The second level consists of Model Reference Adaptive Control (MRAC [8]), this level is responsible for eliminating or preventing the transient oscillation whenever there is an irradiance change. The plant parameter is unknown as it depends on the changing atmospheric conditions and to achieve the better performance MRAC is used. This project to find the adaptive laws to get the desired output, strictly positive real-Lyapunov approach is used. A basic architecture of PV system with MPPT controller is shown in Fig.1 [9].

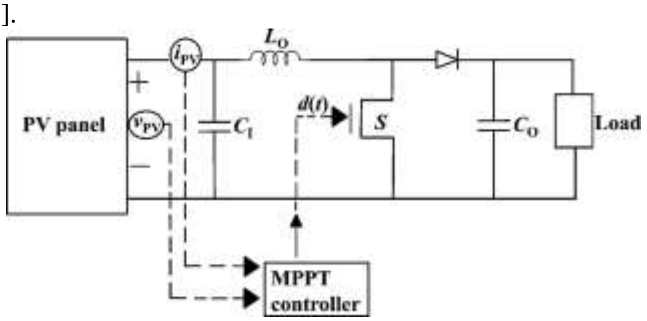

Fig.1. A basic architecture of PV system.

II. METHODOLOGY

To integrate MRAC in MPPT, it is required to find the transfer function of the actual plant model of PV system. To obtain the transfer function, small signal circuit of the PV power conversion system is required, as shown in Fig. 2.

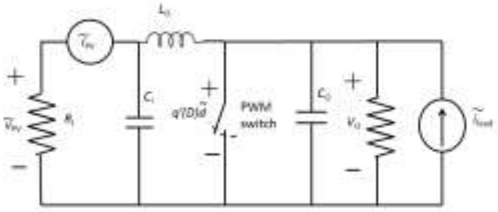

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Fig. 2. Small Signal circuit of PV system [7].

The value R_i is difficult to predict because it depends on the irradiance of the sun throughout the day. Therefore, in order to obtain the characteristics of this nonlinear system linearization at a particular solar intensity is necessary. From the small equivalent circuit equation (1) is derived where $\tilde{v}_{PV}$ represents the difference in the input voltage which corresponds to the solar irradiance change. The overall transfer function of PV system can be presented

$$G_{VP}(s) = \frac{\tilde{v}_{PV}}{\hat{d}} = \frac{\frac{-V_0}{L_0C_1}}{s^2+\frac{1}{C_1R_i}s+\frac{1}{L_0C_1}} \qquad (1)$$

The value of the resistor R_i varies with change in the atmospheric conditions such as irradiance. This in turn also varies the damping ratio producing different step response of the output voltage. Due to change in the irradiance oscillations will occur during the transient period that significantly increases the converging rate of the converter. There is no straightforward method to find the values of the parameters in the transfer function that occurs due to these external changes. Therefore, it is necessary to use MRAC to solve this problem and improve the overall performance of the system.

MPPT Controller Structure

MPPT Controller used in this work consist of two levels. First is the RCC which is used to eliminate the steady state error and secondly the MRAC which is used to remove the oscillations during the transient period. Detailed discussion of both the algorithms are done below.

Ripple Correlation Control (RCC)

RCC is a method that is used to calculate the duty cycle which provides maximum power at the output in steady state. The main advantage of RCC is that it uses inherent ripples that occurs due to the power electronic elements. There are various methods to implement RCC and for this work the design used in [9] has been implemented. Through the correlation of the time-based derivative of voltage and power the RCC tries to identify whether this correlation is greater than zero i.e., to the left of the MPP, or less than zero i.e., to the right of the MPP, or exactly zero i.e., equal to MPP.

$$\frac{dp_{PV}}{dt}\frac{dv_{PV}}{dt} > 0 \; when \; V_{PV} < V_M$$
$$\frac{dp_{PV}}{dt}\frac{dv_{PV}}{dt} < 0 \; when \; V_{PV} > V_M$$
$$\frac{dp_{PV}}{dt}\frac{dv_{PV}}{dt} = 0 \; when \; V_{PV} = V_M \qquad (2)$$

Model Reference Adaptive Control

To achieve the maximum power in steady state RCC is used to generate the duty cycle. During the change in irradiance, oscillations occur in the transient period. It is required that there is a smooth converging towards the MPP due to these external changes in atmospheric condition. To eliminate this problem MRAC is used. As mentioned in the section 2.1.2, due these external atmospheric changes [10-13] the output will not exhibit critically damped behavior without an adaptive control. Fig.3 illustrates the control architecture of MRAC. From the figure it can be inferred that r(t) which is the change in the duty cycle acts as an input to the MRAC system . To design the plant model the transfer function described in (1) from the small signal circuit of the boost convertor has been adopted.

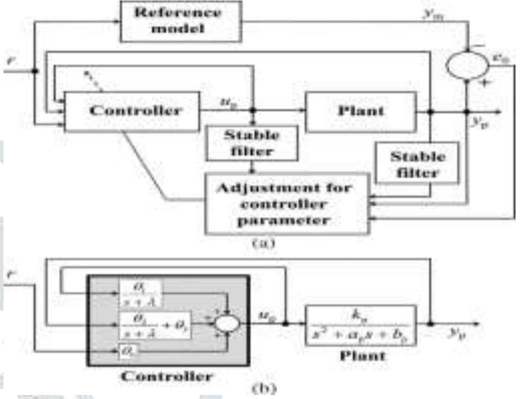

Fig.3. Architecture of MRAC and its control structure.

Equation (3) represents the plant model where $u_p(t)$ is the input and $y_p(t)$ is the output of the plant model. The values of k_p, a_p, and b_p can be calculated by equating this plant model equation to the transfer function equation (1).

$$G_p(s) = \frac{y_p(s)}{u_p(s)} = \frac{k_p}{s^2+a_ps+b_p} \qquad (3)$$

Equation (29) represents the reference model where r(t) is the input and $y_n(t)$ is the desired output. The values of a_m and b_m are determined in such a way that a critically damped output is achieved from the reference model.

$$G_m(s) = \frac{y_m(s)}{u_m(s)} = \frac{k_m}{s^2+a_ms+b_m} \qquad (4)$$

The MRAC rules that have been used to implement the model are represented by the equations below

$$\dot{\omega}_1 = -\lambda\omega_1 + u_p$$
$$\dot{\omega}_2 = -\lambda\omega_2 + y_p$$
$$\dot{\phi} = -g\phi + \omega, \omega = [r, \omega_1, \omega_2, y_p]^T$$
$$u_p = \theta^T\omega + \dot{\theta}^T\phi = \theta^T\omega - \theta^T\omega - \phi^T\Gamma e_0\phi$$
$$\dot{\theta} = -\Gamma e_0\phi \qquad (5)$$

III. SIMULATIONS AND RESULTS

Fig. 4 presents the simulation model that has been implemented on SIMULINK for RCC. The simulation runs for five seconds and the initial value of irradiance is kept at 1000W/m^2. At 2.5 seconds the irradiance changes from 1000 to 600 to show the effect of irradiance on the overall PV System. In the following figures it has been shown that the RCC was able to eliminate the steady state error but during the transient period, oscillations instead of smooth transitions have been observed. Fig. 5 compares the PV power vs output power, where PV Power is represented by dotted red line and the output power from the Boost Convertor is represented by blue line. From this figure it is evident that RCC was able to track the PV Power and eliminate the sudden rise and fall in the PV Power during irradiance change as shown in the figure. Fig. 6 represents the output voltage.

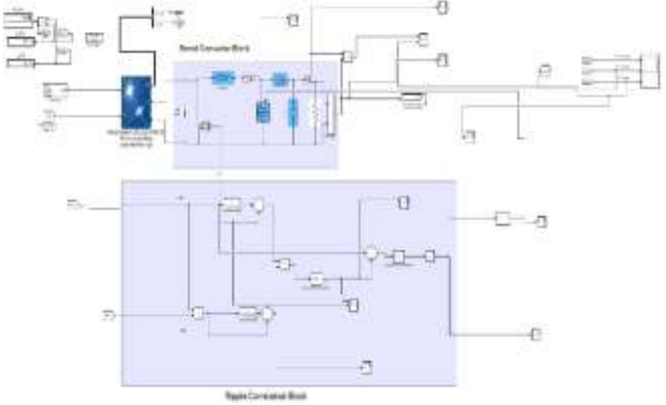

Fig.4. PV Array System along with RCC Block.

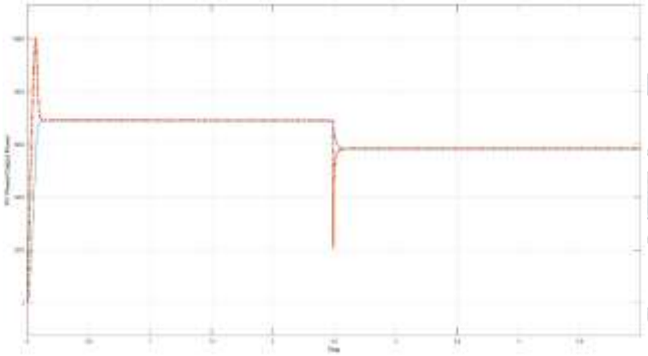

Fig.5. PV Array Power and oscillatory output power without MRAC.

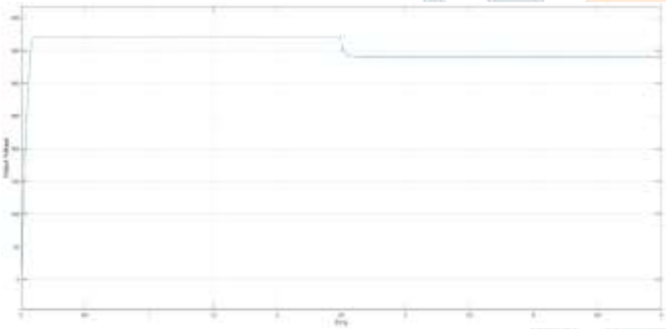

Fig.6. Oscillatory PV output voltage.

Fig.7 shows that during change in insulation the smooth transitioning is not achieved during the transient period. MRAC model as depicted in Fig. 8 ensured smooth transitioning whenever there is a change in irradiance. Fig. 9 represents the output of the reference model. Fig. 10 represents the output of the plant model when no control law is applied to it. Fig.11 represents the output of the plant model when control law is applied to it and it is evident that almost after 0.04 seconds the plant model starts to follow the reference model and the transient performance is improved.

Fig. 7. Oscillations in transient period**.**

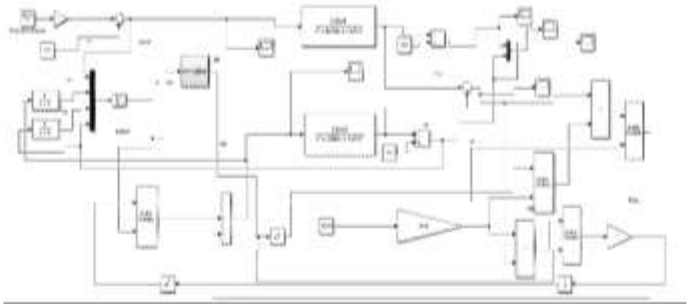

Fig. 8. MRAC Structure.

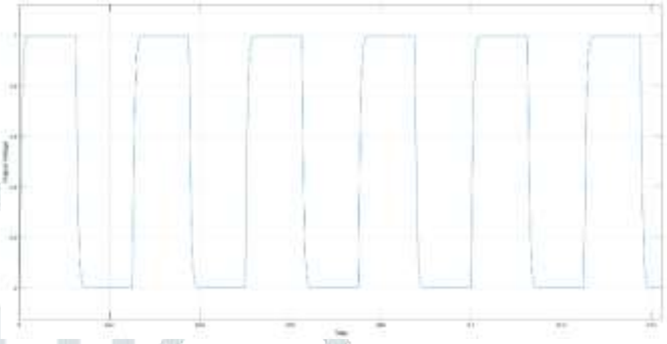

Fig. 9. Output of Reference Model.

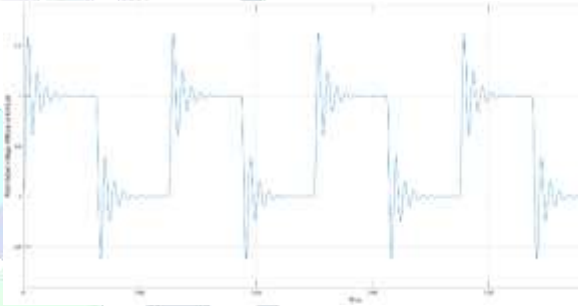

Fig. 10. Output of the plant model without MRAC.

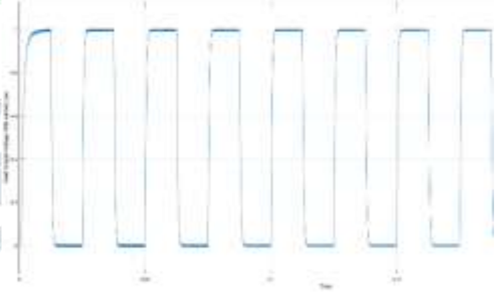

Fig. 11. Output of the plant model with MRAC.

IV. CONCLUSION

This work implemented two level control architecture which can reduce the complexity in system control and can efficiently handle the changing atmospheric conditions. Critical issues in any MPPT algorithm are uncertainty, complexity, and dynamic performance. The algorithms implemented in this project efficiently takes care of these issues.

REFERENCE

[1] Esram, T. and P.L. Chapman, Comparison of photovoltaic array maximum power point tracking techniques. Energy conversion, IEEE transactions on, 2007. 22(2): p. 439-449.

[2] Brunton, S.L., et al., Maximum power point tracking for photovoltaic optimization using ripple-based extremum seeking control. Power Electronics, IEEE Transactions on, 2010. 25(10): p. 2531-2540.

[3] Esram, T., et al., Dynamic maximum power point tracking of photovoltaic arrays using ripple correlation control. Power Electronics, IEEE Transactions on, 2006. 21(5): p. 1282-1291.

[4] Kimball, J.W. and P.T. Krein, Discrete-time ripple correlation control for maximum power point tracking. Power Electronics, IEEE Transactions on, 2008. 23(5): p. 2353-2362.

[5] Logue, D. and P. Krein. Optimization of power electronic systems using ripple correlation control: a dynamic programming approach. in Power Electronics Specialists Conference, 2001. PESC. 2001 IEEE 32nd Annual. 2001. IEEE.

[6] Satish R, Ch L S Srinivas, and Sreeraj E S. A Maximum Power Point Tracking Technique
Based on Ripple Correlation Control for Single-Phase Single-Stage Grid Connected Photovoltaic System

[7] Khanna, R., Zhang, Q., Stanchina, W.E., Reed, G.F., Mao, Z.-H.: ‘Maximum power point tracking using model reference adaptive control’, IEEE Trans. Power Electron., 2014, 29, (3), pp. 1490–1499

[8] T. Messo, J. Jokipii, and T. Suntio, “Steady-state and dynamic properties of boost-power-stage converter in photovoltaic applications,” in Proc. 3rd IEEE Int. Symp. Power Electron. Distrib. Generat. Syst. (PEDG 2012), Jun., pp. 34–40.

[9] P. T. Krein, “Ripple correlation control, with some applications,” in Proc. IEEE Int. Symp. Circuits Syst., 1999, vol. 5, pp. 283–286.

[10] D. E. Miller, “A new approach to model reference adaptive control,” IEEE Trans. Autom. Control, vol. 48, no. 5, pp. 743–757, May 2003.

[11] S. Sastry and M. Bodson, Adaptive Control: Stability, Convergence and Robustness. New York: Dover Publications, 2011.

[12] P. Inoannou and J. Sun, Robust Adaptive Control. Englewood Cliffs, NJ: Prentice Hall, 1996.

[13] Solodovnik, E.V., S. Liu, and R.A. Dougal, Power controller design for maximum power tracking in solar installations. Power Electronics, IEEE Transactions on, 2004. 19(5): p. 1295-1304.