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Optimization of MPPT Control for Solar Energy Systems

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Abstract: *The maximum power point (MPP) of a photovoltaic (PV) power generation system depends on array temperature and solar irradiation is well-known, so it is necessary to continuously track the MPP of the solar array.We can enhance the tracking speed and accuracy by using finite impulse response (FIR) filter predictive control algorithm and hysteresis control method. Simulation is done in MATLAB/simulink. The simulation result shows that this method could track the maximum power point of the photovoltaic (PV) array in time and achieve the maximum power point tracing control quickly and stably.*

Key words *—Maximum power point (MPP), Finite Impulse Response (FIR), photovoltaic (PV), Perturb and Observe (P&O), Maximum power point tracking (MPPT).*

I. INTRODUCTION

As the non-renewable energy sources decreases, the energy crisis and environment pollution is growingseverely. The utilization of solar energy which is clean energyhas been getting increasing interest.

How to improve the efficiency is an important area now days. The Maximum Power Point Tracking (MPPT) which makes the yield of the PV system keeping on the highest value, advances energy efficiency enormously. Thetemperature of PV array varies slowly. When sample frequency is high, the effect ofthe changing temperature can be ignored and themaximum power of PV array is determined by its output voltage [1].

A PV array under unvarying irradiance exhibits a current-voltage characteristic with apoint, called the maximum power point, where the array generates maximum output power. The two majorfactor of moving maximum powerpoint of PV array are the temperature of PV array andradiation intensity.An example of PV module characteristics in terms ofoutput power vs. voltage and current vs. voltage for threeirradiance levels and two temperature values are as shown in Fig.1. The MPP point has been also indicated in both figures [2].

II. OVERVIEW OF MPPT

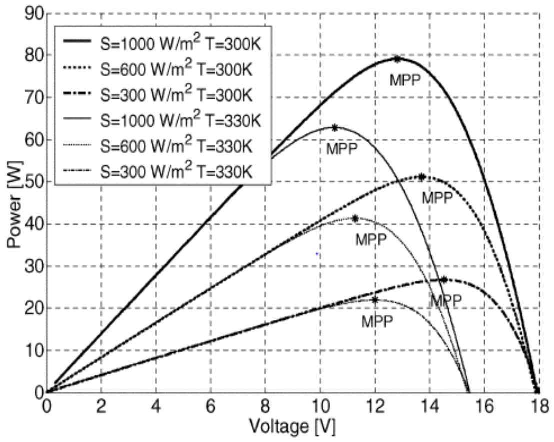
Maximum power point tracking (MPPT) hasdifferentalgorithms. The substance of the maximum power point tracking(MPPT) is an automatic optimization process[2][3]. Somealgorithms of MPPT which is commonly used include: Perturbation and Observation Method (P&O)[4], Fixed Voltage Method [5], Conductance Increment Method [6], Intermittent scanning Method and IntelligentControl Method[7].Perturb and observe (P&O) and Incremental Conductance(INC) techniques are commonly used, particularly for low-costimplementations.The P&O algorithm is generally used, due to its easeof implementation.The operating voltageof the PV array is perturbed by varying the duty-cyclein a given direction and power drawn from the PV array is probed, if it increases, the operating voltageis disturbed in the same direction, while, if itdecreases, then the direction of operating voltagedisturbance is reversed [1].A weakness of P&O MPPT technique is that, at stable state, the operating point oscillates about the MPP give rise to the wastage of some amount energy. Several enhancement of the P&O algorithm have been proposed in order to decrease the number of oscillations about the MPP in steady state, but they reduce the speed of response of the algorithm to varying atmospheric conditions and lower the algorithm efficiencyduring cloudy days [2].This paper proposes a MPPT hysteresis controltechnique based on FIR filter predictive control algorithm with RLS algorithm to make up for the weakness above.

III. PREDICTION MACHINERY

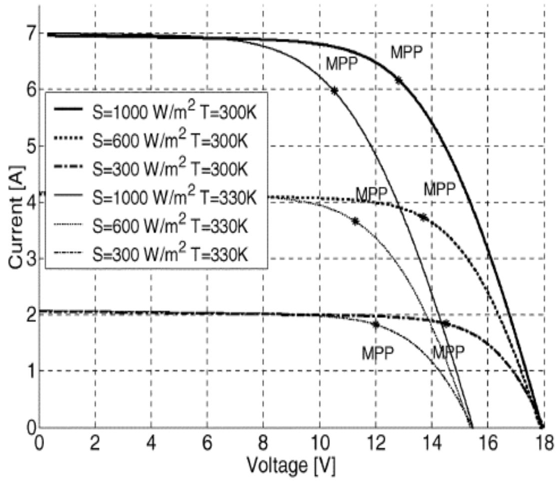
This system use an adaptive prediction model based onFIR. The output is denoted as a linear combination of present input and past output [8]:

$$\hat{y}(n+1) = \sum_{K=0}^{N-1} h_x x(n-k) = H_N' X_N(n) \quad (1)$$

$X_N(n)$: Input vector of adaptive predictor,



(a)



(b)

Fig.1.PV module characteristics for three irradiance levels S and two different panel's temperature: (a) output power vs. voltage and (b) current vs.voltage [1]

X_N(n) =[x(n),x(n-1),….x(n-N+1)] ; H'_N; coefficientvector of adaptive predictor , which is the key factor ofprediction machinery, $H'_N=[h_0,h_1,....h_N]$; N :thenumber of linear combination , it is another factor which influence the prediction algorithm[9]; h_K: The elementof corresponding coefficient vectors.The functional block diagram of prediction machineryis shown in Figure 2. y(n) is desired output; y^(n)andy^(n+1) are predict results; e(n) is the error betweendesired output and predict results.

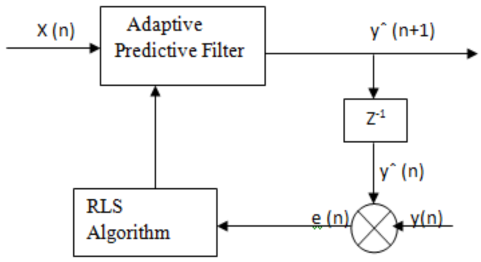


Figure 2: Prediction machinery

Generally theoptimization criterion is based on minimum mean squareerror value of forecast error. The typical one is RLS(Recursive Least Square) algorithm.The main idea behind RLS filters is to reduce a cost functionC by properly selecting the filter coefficients w_n , updating the filter as fresh data arrive. The relation between error signal e(n)and desired signald(n) are defined as below:

$$e(n) = d(n) - d\hat{}(n)(2)$$

The weighted least squares error function C, the cost function we want to minimize ,being a function of e(n) is also dependent on the filter coefficients.

In this method, the key of MPPT control is to balance rapidity and accuracy. The speediness of the system is improved by prediction algorithm and the precision of the system is enhanced by hysteresis control. Figure 3 shows control block diagram of MPPT. p(n) is the output power of thistime.

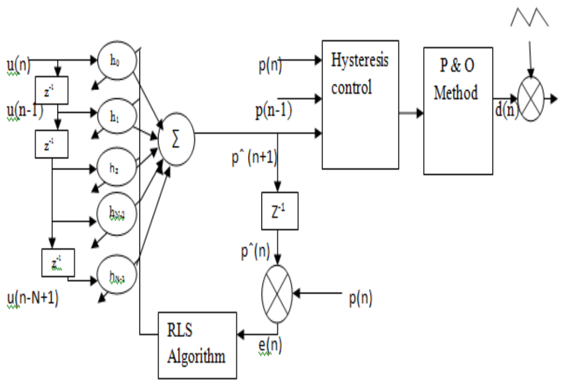


Figure 3: control block diagram of MPPT

p (n −1) is the output power of last time.d(n) is duty cycle. The input voltage predicts the output power of next moment by prediction machinery. And then the system enters a judgment based on control rules. Hence the duty cycle can be determined and PWM pulse signal which can drive switching devices after comparison between duty cycle and triangular wave is generated.

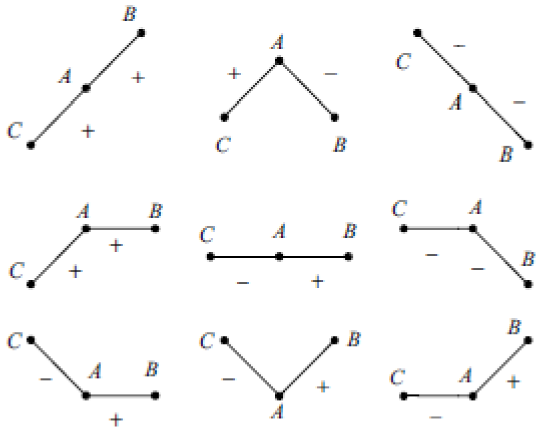


Figure 4: A sketch of comparison among three powers[1]

In adaptive prediction machinery, X (n) is vectorof output voltage in the past:

X(n) =[u(n),u(n -1),....,u(n - N +1)] . Y (n) isvector of output voltage in present. yˆ is predictedpower of next moment.

In hysteresis control, P_A is the output power of this moment. P_B is the MPP of next moment which is predicted. P_C is the output of last moment. When P_A>P_C, mark it with "+". When P_B> P_A, mark it with "+". If not, mark it with "-" as shown in the figure 4 [1].

Three rules can be summarized through the above the statement:

Rule 1: If two powers of perturbation are "+", then voltage keeps the disturbance direction.

Rule 2: If two powers of perturbation are "-", then voltage keeps the opposite disturbance direction.

Rule 3: If one of it is "+" and another is "-", voltage remains unchanged as it has reached MPP or illumination intensity is changingtoo fast.

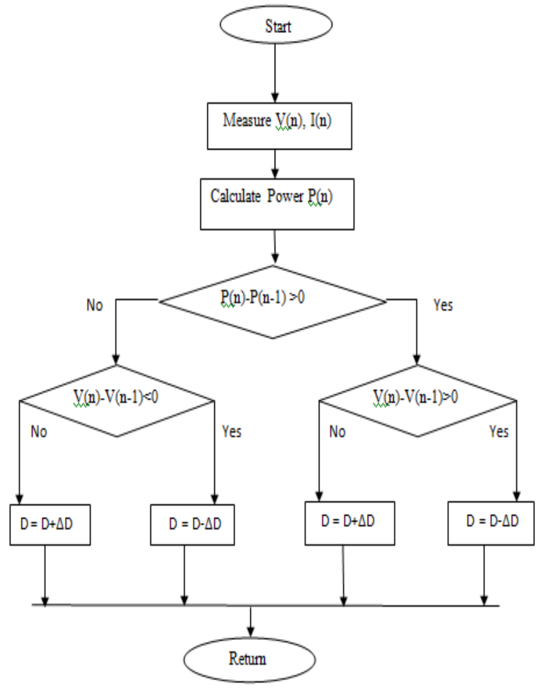


Figure 5: Flow diagram of MPPT algorithm based on prediction machinery using adaptive FIR filter

IV. SIMULATION RESULT

A simulation system based on predictive algorithm isbuilt on MATLAB/simulink for verifying the theorywhich is proposed in this paper. And it makes comparison with Perturbation and Observation Method using LMS algorithm. The key parameter of PV array are as follows: Voc=42V, Isc=29.7A, Vm=36V,Im=27.7A,C1=2000uF,C2=1600uF, L=2Mh. Boost converter with inductance of 2e-3H and capacitance of 2000e-6F isused to step up the voltage to the necessary value.

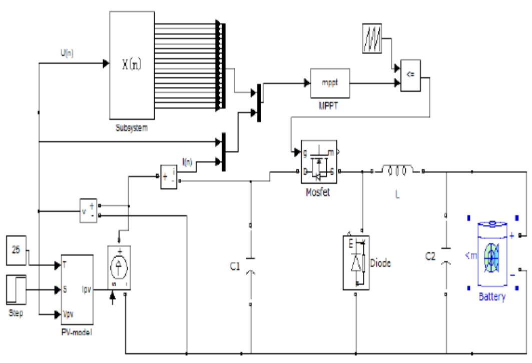


Figure 6: Simulink Model of solar energy PV System.

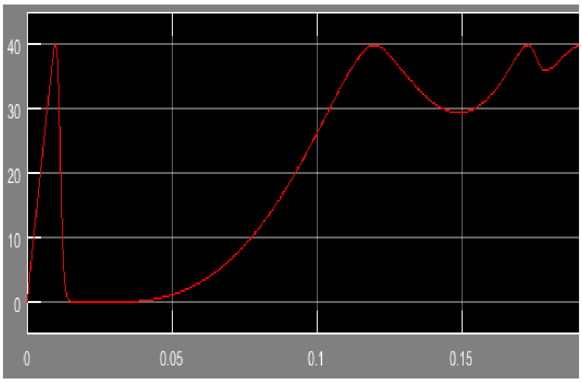


Figure 7: Output power (W) of P & O using LMS algorithm

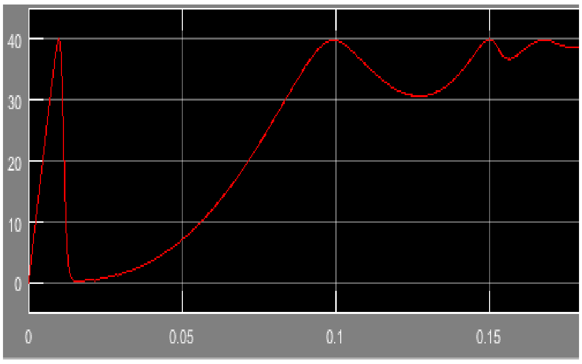


Figure 8: Output power (W) of P & Ousing RLS algorithm

By using the same parameters in all blocks such as temperature, irradiance value etc. Propose method performs well as compared to the Perturb and observe method with LMS. The system starts tracing at 0s in both methods. Old method gets poor tracking in the start and stables the Maximum power point afterlong period of time as shown in Figure 7 and the hybrid method takes only 0.1s toachieve the maximum power point (MPP) as shown in Figure 8. The secondimprovement that has been achieved by proposed method is that the range of powerproduced more précised signal than the P & O with LMS method.

V. CONCLUSION

In this paper, a new MPPT hysteresis control method based on FIRmodel predictive control algorithm is proposed. This control method is based on P&O and combines adaptive predictionmachinery using RLS algorithm and hysteresis control. The system predicts the output power of nextmoment and after that determines the disturbance direction by using rules. It maintains the tracing velocity with the controlaccuracy and also reduces the system loss. The simulationresults proves that the new algorithm has high tracing speed means takes less time to reach maximum power point (MPP) and high stableprecision than the previous work.

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