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MPPT for PV Systems Based On Optimization Algorithm

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Abstract
Since the power–voltage characteristic curve of photovoltaic (PV) arrays has multiple peaks under partially shaded conditions, the conventional maximum power point tracking (MPPT) control methods willfail to work. However, the particle swarm optimization (PSO) algorithm is very suitable to solve themulti-extreme optimization problem. Then this paper proposes a dual-algorithm search method: first,a dormant particle swarm optimization (DPSO) algorithm is activated to search the area of global peak, and then the algorithm will be switched to conventional incremental conductance (INC) algorithm totrack the maximum output power of photovoltaic arrays. During the iteration process of DPSO, if particles happen to search repeatedly or sway in a small region, they will be turned into dormant state so asto reduce convergence time and improve efficiency. Due to the elimination of searching repeatedly, thenumber of particles can be large to strengthen optimization capability. In addition, the optimal number ofparticles for DPSO is found by analysis and simulation. Furthermore, the searching sequence of particlesis optimized to effectively reduce fluctuation of voltage and suppress output voltage spike. Finally, theexcellent performance of the proposed model is verified by simulations and experiments

Key Words:- MPPT , PSO , DPSO, Voltage Spike.

Introduction

Solar energy is a very popular source of renewable energy dueto several advantages. Photovoltaic (PV) power systems have beenwidely used in many countries. However, there are many urgentissues to tackle in the application of PV power systems. One of thecentral problems is how to improve efficiency [1–3]. Since the PVarrays exhibit a nonlinear power–voltage (P–V) characteristic curvewhich varies with insolation and temperature, how to achieve maximum power point tracking (MPPT) is a very important technology[4,5].To date, various conventional MPPT schemes have been pro-posed including hill-climbing (HC) [6–8], perturb and observe(P&O) [9–12], and incremental conductance (INC) [13–16], etc.These methods have simple structures and low equipment requirement, but they cannot handle the partially shaded conditions (PSC)because P–V curve displays multiple peaks with several local peaksand a global peak (GP), which cannot be differentiated by conventional algorithms. However, PSC occur quite commonly due tosun position, clouds, buildings, trees, and so on, so it is necessaryto improve these algorithms to track the actual GP. Then several attempts have been suggested by researchers in Ref. [17–20].

Authors in Ref. [17] have reported an MPPT scheme that usesFibonacci sequence to track the GP under PSC. However, the methoddoes not guarantee GP tracking under all conditions. Authors in Ref.[18] proposed a two-stage method to track the GP. In the first stage,the region of the GP is detected using the load line, and in the secondstage, the operating point converges to the GP. But, this method mayfail to track the GP if the GP lies on the left side of the load line. Inanother work [19], authors proposed a two-stage approach. Despiteits effectiveness, the method needs to scan almost 80% of the I–Vcurve to find

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the GP, which will lead slow response. In Ref. [20],authors proposed a dividing rectangle (DIRECT) search method,which is based on a Lipschitz condition to find the GP. However,the algorithm is very complex, which will increase the burden ofsystem significantly.The essential issue of MPPT control is an optimization problem which can be achieved by using evolutionary algorithm. PSOalgorithm owns the characteristics of parallel processing, goodrobustness, and high probability of finding global optimal solution.Because of its good performance in multiple-peak function optimization, PSO is very suited for MPPT control of PV system underPSC [21–27]. However, in all of these PSO methods, the searching paths of particles will overlap. Because some particles will gothrough the path which have been searched by others lying onthe same side of GP. This phenomenon of searching repeatedly isvery common in above PSO methods, which results in slow convergence speed. Additional, due to the initial positions of particlesand distribution of local peaks and global peak, some particles willway or cannot get to the GP under certain conditions. This paperproposes a new dormant particle swarm optimization (DPSO) algorithm, in which the particles searching repeatedly or swaying in asmall region will be turned into dormant state. Thus, the speed andefficiency of MPPT will be greatly improved. The DPSO algorithm,together with INC algorithm which aims at tracking the maximumpower point precisely, constitutes the dual-algorithm model, whichis simple to implement and can achieve MPPT rapidly and accurately under PSC.The remainder of the paper is organized as follows. SectionII briefly introduces the conventional PSO (CPSO); Section IIIdescribes the proposed DPSO & simulation result; While in Section IV, theperformance of DPSO to track GP is simulated and experimented. Finally Conclusion is given in section V.

CPSO

CPSOPSO, as a new swarm intelligence optimization algorithm, firstlyproposed by Kennedy and Eberhart in 1995 [18], has been developing rapidly in recent 20 years. It is modeled according to thebehavior of bird flocks. Its advantages are simple realization andfast convergence, and it is well applied to find the global optimalsolution in a nonlinear, discontinuous, no differentiable curve [19].In this algorithm, several cooperative particles are used in an n-dimensional space. Each particle owns its position pi(distributedrandomly) and velocity *v*i(*v*i= 0 in initiation). The position of a particle is influenced by its best position so far, P-besti, and the bestposition of all particles so far, G-best. Velocity.This paper has analyzed and improved the structure and parameters of CPSO to make it more practical and effective. Randomnumbers in equation (1) mainly help to ensure the capacity tosearch any potential local peaks; however, they are not necessaryin MPPT control based on simple P–V curve. Moreover, two potential problems can be observed when simulating [30]. First, if therandom number is small with the present information of controlvariable (duty cycle is adopted in this paper), only a small change inthe velocity term of the PSO equation is obtained, which will resultin more iterations needed by CPSO. Second, if the random numberis close to 1 when the power values of local peaks and GP are similar, CPSO may escape from the GP. To handle these drawbacks, therandom numbers are removed and velocity factor is limited to a certain value Vmax, which is set according to the distance between two peaks

Simulation Experiment

Standard boost converter is utilized to implement MPPT controlin this paper, as shown in Fig. 5. In the mode, the PV arrays consistof three commercial PV modules MSX-60 connected in series.Table 2 provides the key parameters of the module includingsampling time of two algorithms TDPSOand TINC, number of particlesNp, and initial positions of these particles pi. The other parametersare analyzed in Refs. [10,11].

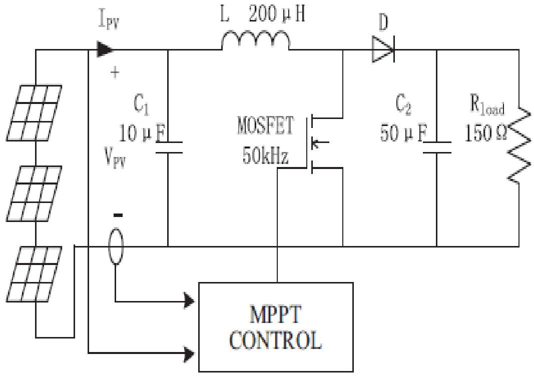

Fig 1 Simulink Model of PV grid System with MPPT Control

As we can see in Fig. 1, with the same sampling time, the dual-algorithm model with CPSO and INC algorithm need take longertime than DPSO to converge all particles under STC. Under somespecial conditions, not all particles will converge to GP, and someof them may sway between G-bestand its P-besti(i.e., case 2). Then, inbrief, CPSO is low efficient because particles search repeatedly orsway.

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Simulation Result

Solar panel TOP90(12)1210 × 560 is used in experiment withfollowing specifications: the maximum power of solar panel(under STC) PMPP= 90 W, voltage at maximum power point (MPP)VMPP= 17.5 V, current at MPP IMPP= 5.4 A, open circuit voltageVOC= 22 V, short circuit current ISC= 6.02 A. The switching frequency of boost converter is 50 kHz. The main experiment devicesare shown in Fig. 1.The sun is shining brightly at noon during experiments. AsDC/DC converter is connected with purely resistive load, we acquirethe voltage waveform (similar to power waveform) of load. First,the output voltage waveform of the PV arrays under partiallyshaded condition shown in Fig. 2 is obtained by utilizing globalscanning method. According to it, we know that the output ofthe PV arrays under this partially shaded condition contains aglobal peak point and two local peak points. Then the dual-algorithm model with DPSO and INC, dual-algorithm model withCPSO and INC and conventional INC algorithm are respectively usedto track the maximum power point when the PV arrays are underthis partially shaded condition. However, obviously, convergence time of DPSOis quit shorter than CPSO, and voltage waveform of DPSO is gentler,too.

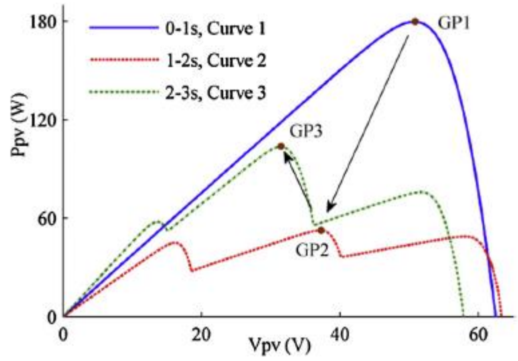

Fig 2 VoltageVs Power Curve of different algorithm

In addition, Fig. 2 can be obtained by adopting the conventionalINC algorithm to track the maximum power point when PV arraysare under partially shaded condition (i.e., insolation is 400, 900, and1200 W/m2in turn, and temperature is 40◦C, so the P–V curve of PVarrays is curve 3. Obviously, the conventional INC algorithm tracksa local peak instead of the GP. So the conventional INC algorithm isnot suitable to handle partially shaded conditions.Simulation results show that the dual-algorithm model consisting of DPSO algorithm and INC algorithm could find GP quickly andsuccessfully and maintain the operating point at GP no matter howFig. 10. Experiment devices.complex the P–V curves are. Meanwhile, under three shaded conditions, the convergence times are almost the same and obviouslyshorter than CPSO.

Conclusion

In this paper, a dual-algorithm MPPT control model based onDPSO and INC is proposed. The results of simulation and experiment show that, compared with CPSO and conventional INC, theDPSO greatly shortens the searching time, reduces the fluctuationof output waveform and improves the efficiency through particles dormancy and activation control, optimal number of particlesalgorithm and search sequence selection. Meanwhile, the INC guarantees that the GP can be tracked precisely. This dual-algorithmmodel has good performance no matter how complex shaded conditions the PV arrays are under.

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