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Insensitive Differential Evolution for Exploring Maximum Power Point

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Abstract—This paper studies an insensitive differential evolution and its application to exploring the maximum power point in photovoltaic systems. Depending on the insolation, the maximum power point varies and complicated multi-peak is generated. Our algorithm has a key parameter that controls particles insensitivity that can be effective to prevent trapping of particles. Performing basic numerical experiments, the algorithm efficiency is investigated.

1. Introduction

This paper studies the insensitive differential evolution (IDE) and its application to exploring the maximum power point in photovoltaic systems. Outline and background of DE:

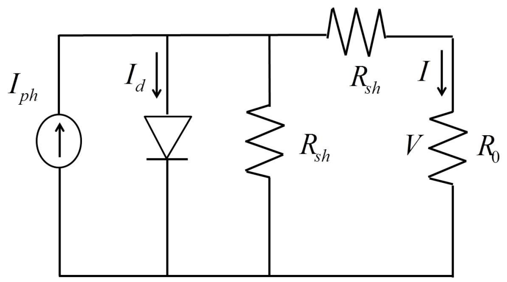

Figure 1: Equivalent circuit of a solar cell

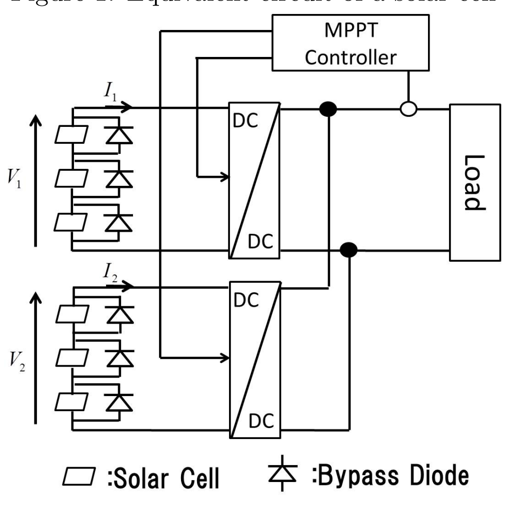

Figure 2: The paralleled PV system

The Difference Evolution (DE [1][2]) is an optimization technique. Each particle is a potential solution. Applying crossover and mutation, the particle location is updated and the particle try to find the optima. The DE is simple in comcept, easy to implement and have been applied to various emgineering systems: signal processing, power electronics, and communication systems[3][4].

This paper presents the IDE that can be insensitive depending on position of particles. In the IE, each particle has a territory. If the location of a particles is included in the territory, the particles movement is reinforced.

We apply the IDE to exploying problems of the maximum power point(MPP) in photovoltaic systems[5][6][7]. The MPP tracking is an important technique in renewable energe supply system. Depending on the isolation, the power characteristic varies and may become complicated multi-peek shapes.

If we apply standard DEs, it is hard to explore the MPP in the multi-peek problem becouse the particles often trapped into local peeks. The insensitivity of the IDE can be effective for escape from the trap. Performing basic numerical experiment for typical example, efficiency of the IDE is confirmed.

2. Objective Problem

Here we define the objective function. Figure 1 shows equivalent circuit of a solar cell. For simplicity, Rs and Rsh are ignored. The ciruit is characteristeced by the parameters: I_{ph}=photo-generated current. I_{rs}=cell reverse saturation current. q=elementary charge. k=boltzman constant. A=diode ideality factor. The $V-I$ characteristics describesd by

$$I \equiv f(V) \equiv I_{ph} - I_{rs}\left(\exp\left(\frac{qV}{kATn_s}\right) - 1\right) \qquad (1)$$

We consider a multiple solararray system as shown in Fig.2. It includes two sets of three solar cells connected in series. They are controlled by single MPPT controller.

The PV characteristics is shown in Fig.3. Note that the cells have different isolation. The power characteristics is given by

$$F(V_1, V_2) \equiv V_1 f(V_1) + V_2 f(V_2) \qquad (2)$$

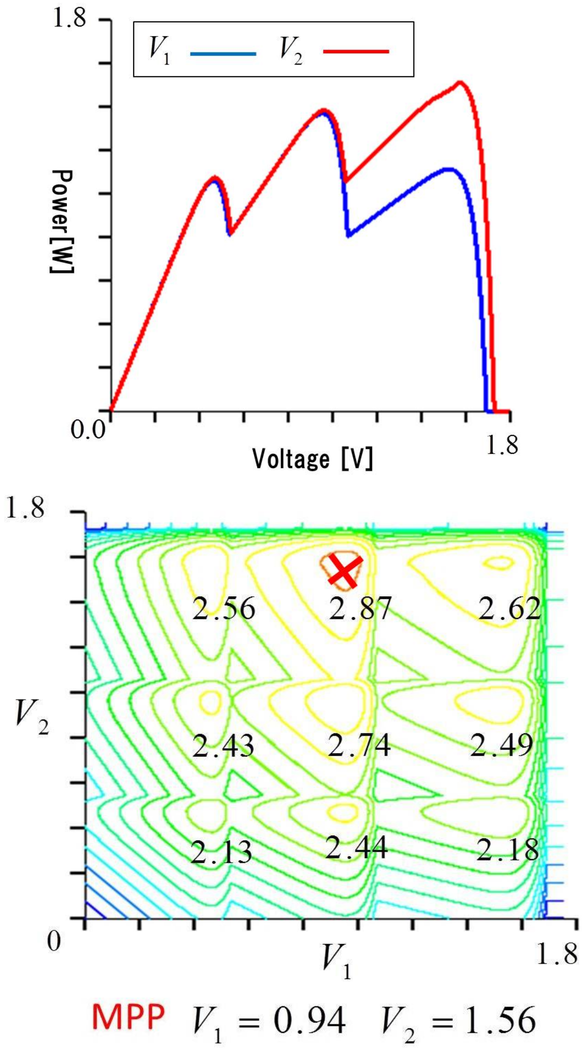

Figure 3: Objective function

Figure 4 show the contour map. The function F is the fitness of the IDE in this paper.

3. Insensitive Differential Evolution

The IDE operation is based on the location of particles and the fitness function. Let x_i^n be the $i-$th particle position at step n. We use plural particles in this paper. However, note that MPPT controller has single operating point corresponding single particle. It is hard to use plural operating point in practical system. Applying virtual particle technique is [8], the single particle can be translated in plural particles.

Step 1 (Initialization): Let step $n = 0$. The particles location X are initialized. The particles location are set randomly in the search space S_0

Step 2 (Mutation): The Gbest n_B^n is selected. Two vecters x_{x1}^n and x_{x2}^n selected randomly. offspring is genelated by the follwing:

$$x_i^{new} = x_B^n + S(x_{p1}^n - x_{p2}^n) \tag{3}$$

where S is scaling parameter.

Step 3 (Crossover): Applying crossover to the offspring and the parent x_i^n, we obtain the next offspring x^{new}1. where $i = 1 \sim N$. The offspring is inherited with probability CR. The CR is referred to as the crossover rate.

Step 4 (Survival):

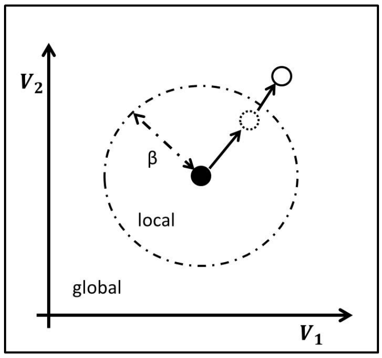

Figure 4: Neighbour-dependent insensiivity

The ditance of particle movement is measured and is reinforced as illustrated in fig.3. The offspring location is updated as the follwing:

$$\begin{aligned} &x_i^{new} = x_i^{new} + \alpha(x_i^{new} - x_i^{n-1}) \\ &\text{if } (x_{i_x}^{new} - x_{i_x}^{n-1})^2 + (x_{i_y}^{new} - x_{i_y}^{n-1})^2 \leq \beta^2 \end{aligned} \tag{4}$$

where α is the scattering rate.β is the territory radius. The location is measured by the Euclidean distance.

The parent x_i^n is updated as the follwing:

$$\begin{aligned} &f(x_i^n) < f(x_i^{new}) \ then \ x_i^n = x_i^{new} \\ &otherwise: \ x_i^n = x_i^{n-1} \end{aligned} \tag{5}$$

Step 5 (Termination Condition): Let n=n+1, go to Step2 and repeat until the time limit n_{max}.

4. Numerical Experiments

In order to confirm the algorithm efficiency, we have performed basic numerical experiment. The scattering rate α is selected as a control parameter. For sinplicity, the other parameters are fixed: scaling parameter $S = 0.6$, crossover rate $CR = 0.7$, the number of particles $N = 10$, time limit $n_{max} = 30$ scattering rate $\alpha = 0.35$ and territory radius $\beta = 0.7$. In order to evolute the performance, we introduce two measures:

SR:The rate of successful runs where the Gbest exceed $2.86[w]$(The $MPP = 2.86$).

#ITE: The average number of iterations in successful runs.

Figures 4 (a) and (b) show typical examples of snapshot in the search process of IDE and DE, respectively. Figures 5 (a) and (b) show search process of IDE and DE, respectively. In the IDE, the particles are distributed and can find the MPP. In the DE, the particles tend to be trapped into the local peeks, and hard to approach the MPP. Figures 7 (a) and (b) show the SR and #ITE for α. As α increases the particles tend not to be trapped into local peak and the seach speed becomes slow. $\beta = 0.7$ gives the highest SR. There exists a trade-off between the SR and #ITE as expected.

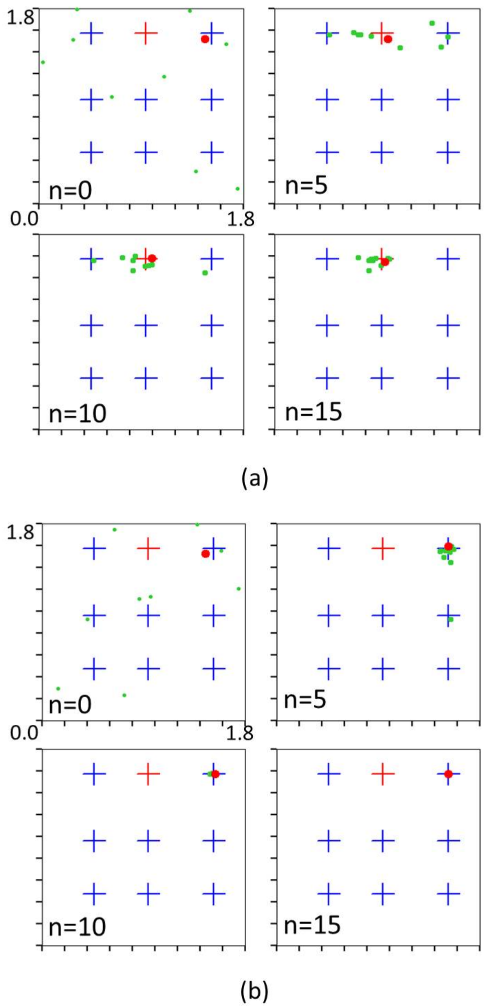

Figure 5: Typical examples of expliring the MPP. (a) A successful run of IDE (b) A failed run of DE The red circle is the gbest

5. Conclusions

Territory-dependent IDE and application to MPP search are studied in this papper. Exploring basic plo- blem, we have comfirmed that the diversity of particles

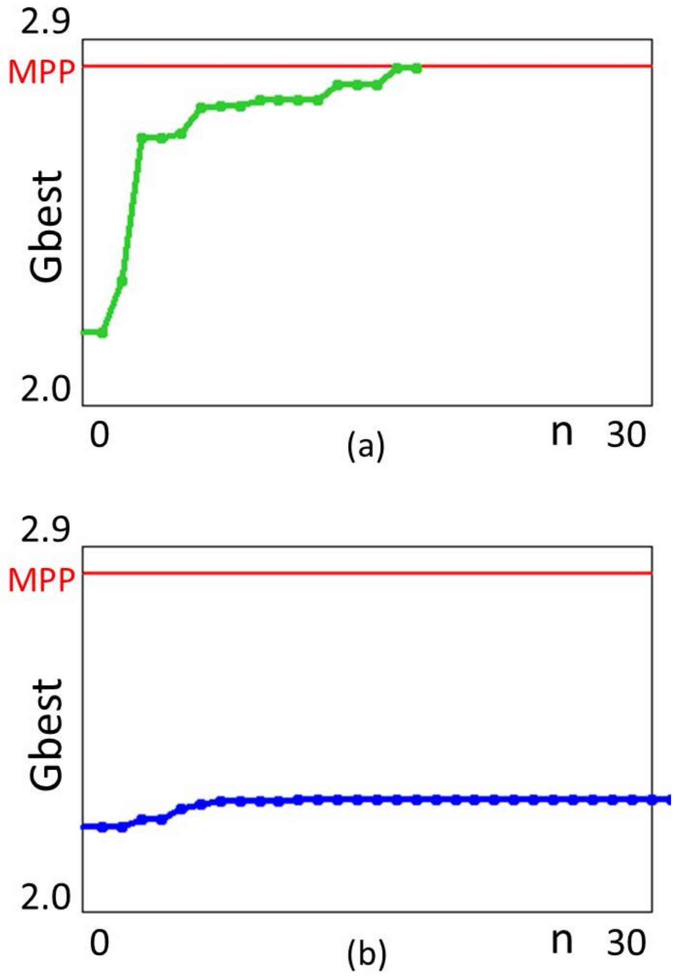

Figure 6: Exploring process (a) A successful run of IDE (b) A failed run of DE

can be controlled and the MPP can be found successfully. Future problems include analysis of relation between effect and various parameters.

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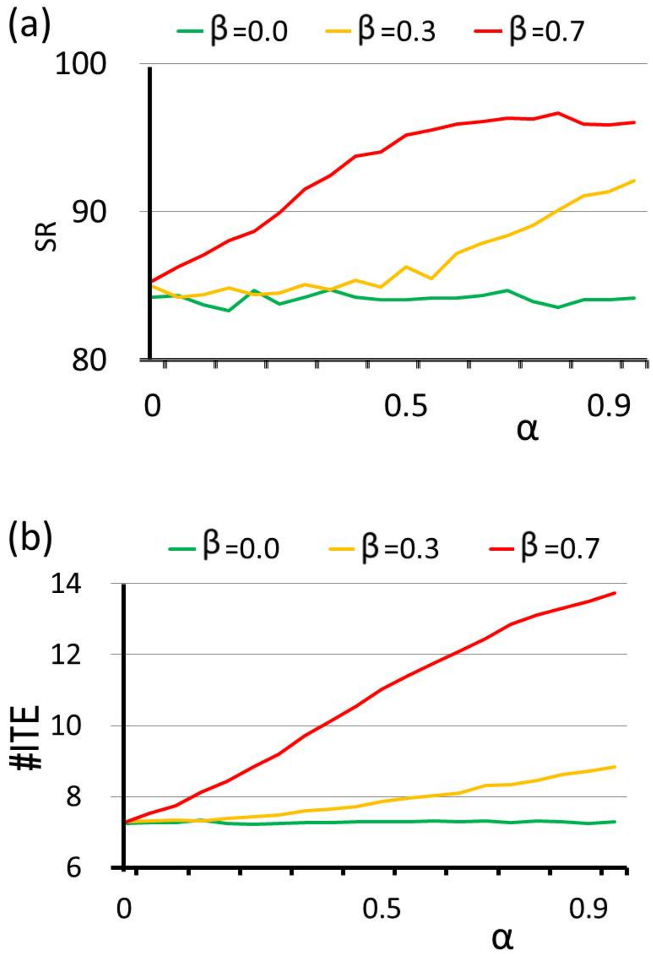

Figure 7: Performance for control parameter α. (a) The average successful rate (b) The average number of iterations

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