Control Characteristics of a Fibonacci-Search-based Maximum Power Point Tracker When a Photovoltaic Array Is Partially Shaded

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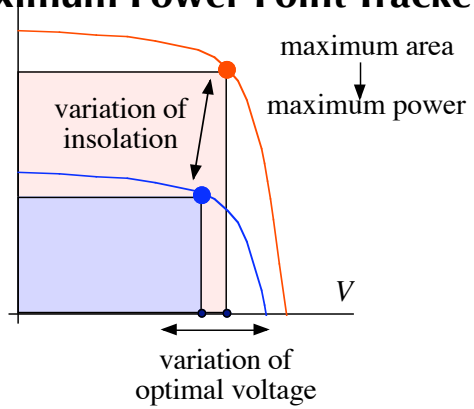
Introduction

General Background

- Needs for photovoltaic (PV) power
  - reduction of CO_2 emission
  - distributed power generation
- Features of PV power generation
  - dependent on weather
  - change of the operating point generating maximum power

→ **Maximum Power Point Tracker (MPPT)**



Partial Shadow Effect

- **Partially shaded PV array**
  - with series connection of PV modules
  - two or more maximum power points
  - difficulty in finding the global maximum power point

Objectives

- **Simple and fast algorithm**
  - small amount of calculation
  - intuitive parameter tuning
- **Reliable algorithm**
  - able to find the global maximum power point
- **Applicable to any type of power conditioners**
  - independent of the circuit configuration

→ **Various applications are expected.**

Fundamentals of the MPPT

Approach

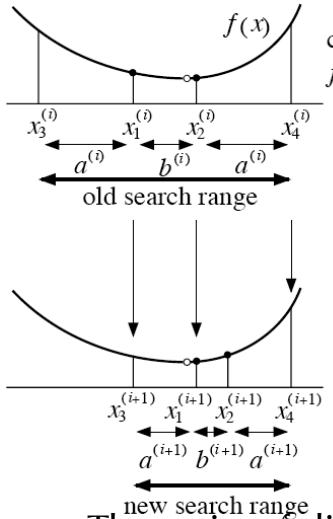
- **Using simple optimization methods**
  - no need for differential operation
  - no need for assumption of function itself

→ **Difficult to use some methods applying Maximum Principle**

- **Two types of optimization techniques**
  - one dimensional line search algorithms
    - very simple
      - Fibonacci search algorithm
      - (golden section search algorithm)
  - introducing meta-heuristics
    - easy to find global maximum point
      - Particle Swarm Optimization (PSO)

Using Fibonacci Sequence

$c_{n+1} = c_n + c_{n-1} \quad c_1 = c_2 = 1$



comparison of $f(x_1^{(i)})$ and $f(x_2^{(i)})$

$c_1, c_2, \ldots c_N$

if $f(x_1^{(i)}) > f(x_2^{(i)})$ ⇨ shifting search range right

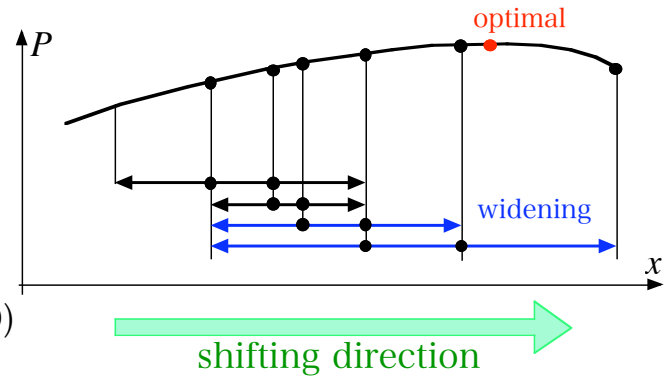
else ⇨ shifting search range left

restricting search range

simple and fast !

only comparing and restricting

- The ratio of divisions satisfies the Sequence.

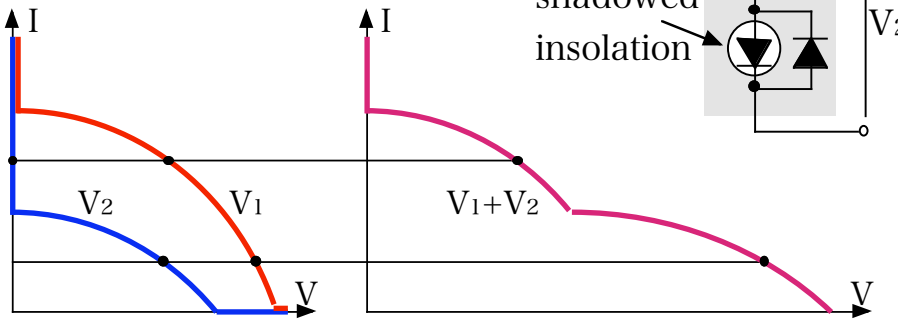


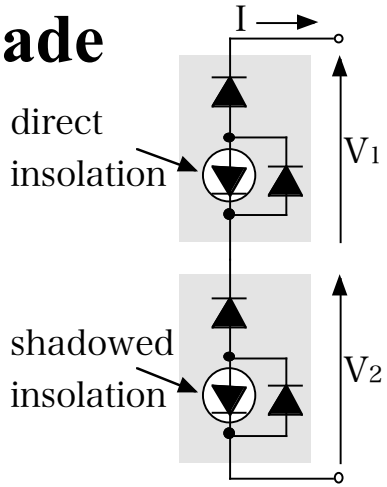
If the optimal point is out of the search range...

Improvement of the Proposed MPPT

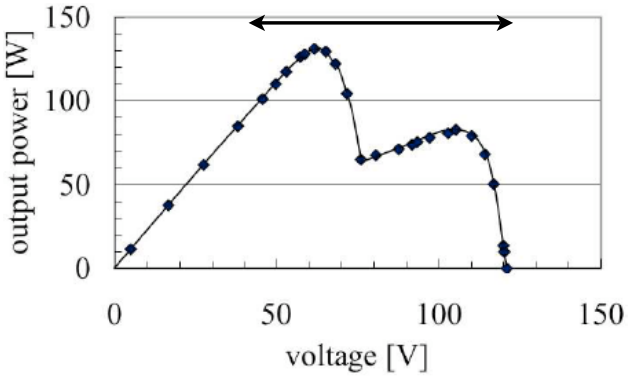
Effect of partial shade

Partial shade and series modules often generate two or more maximum points.





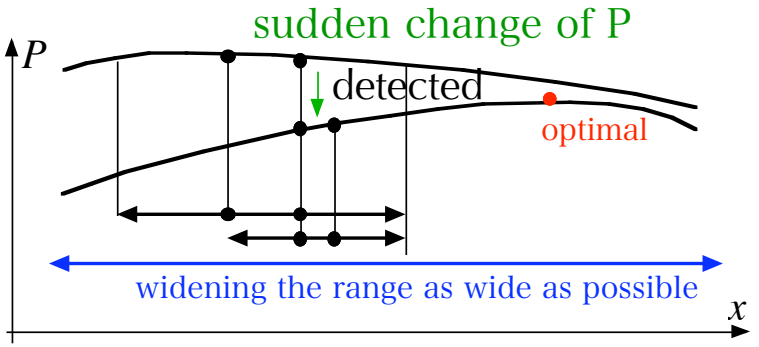
need for wide range search



example of P-V characteristics

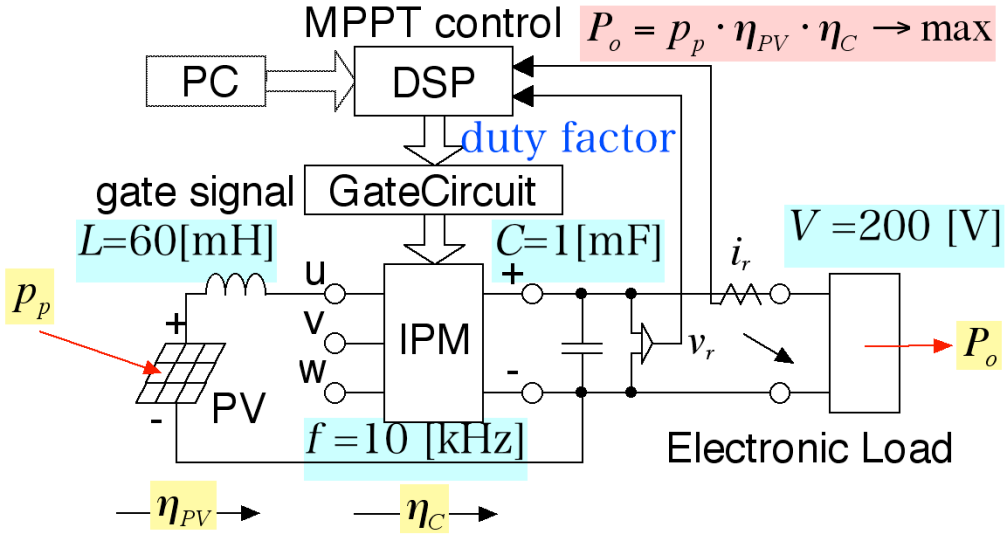
Initialization of search range

in order to find global maximum power point easier.



Experimental System

Circuit Configuration

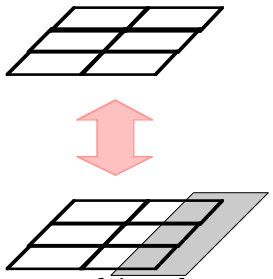


6 series modules (rated power : 300W)

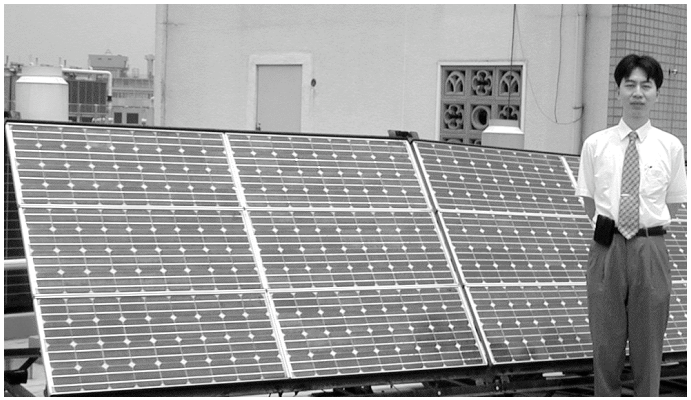
An Intelligent Power Module (IPM) is used as a boost converter.

It can control three PV arrays simultaneously.

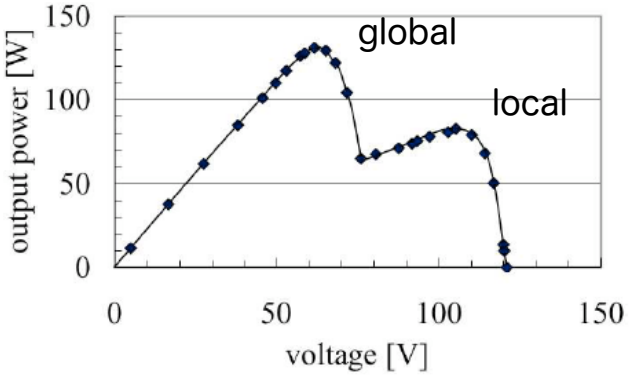
To make artificial shadow



realizing sudden change of insolation

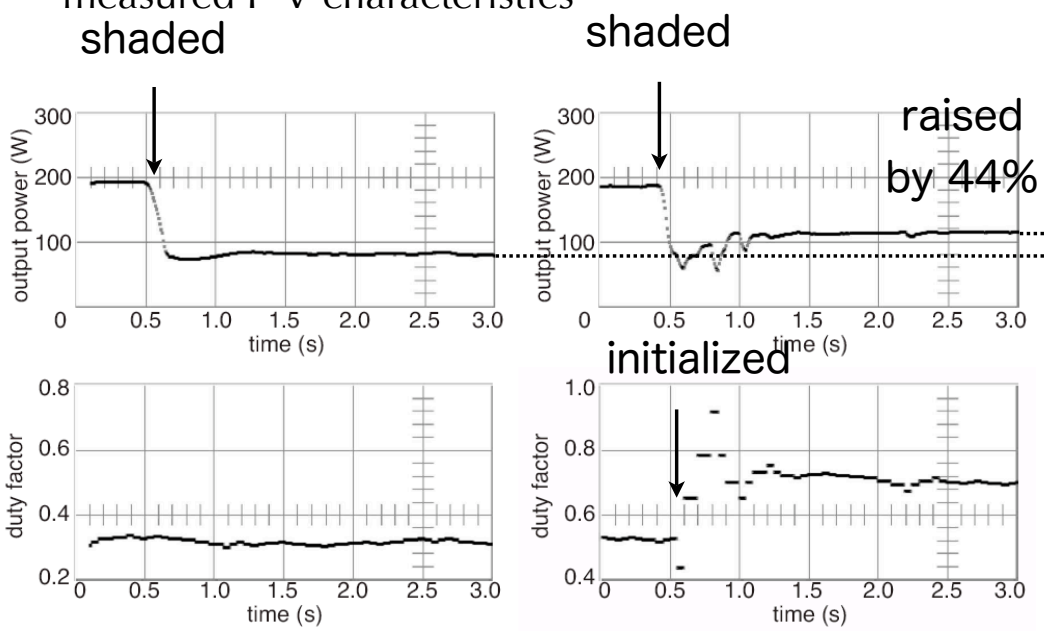


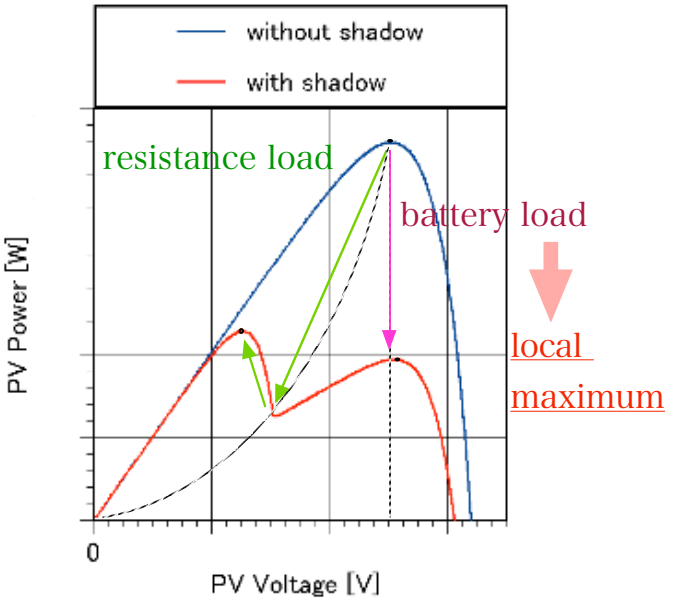
Results of the Experiments



measured P-V characteristics

- The improved MPPT does NOT always finding the global maximum theoretically.
- It can raise output power with partially shaded array in most cases.
  - balancing simplicity and performance
  - reasonable MPPT
- Fast power fluctuation can be found.

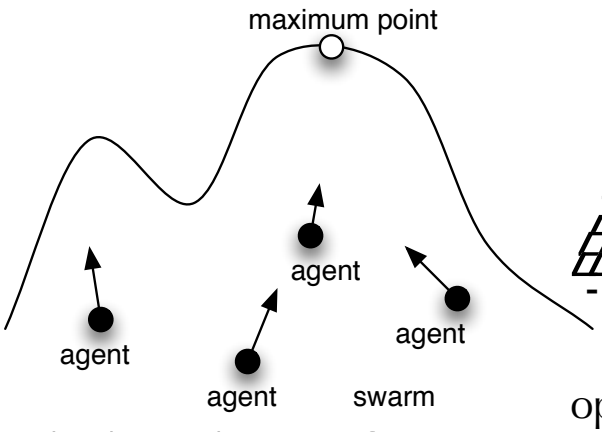


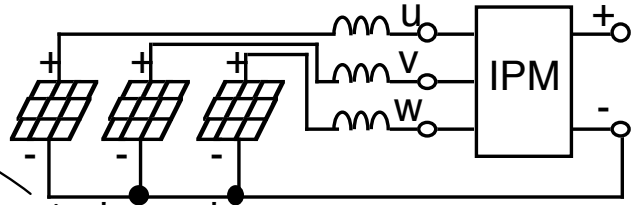


Further Works

Application of PSO method

- **Controlling the movement of agents**
  - easy to find the global maximum power point
  - applicable to multi-dimensional control

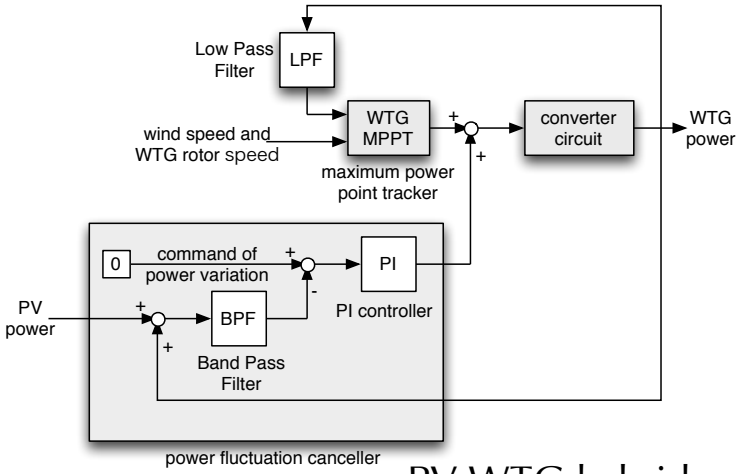




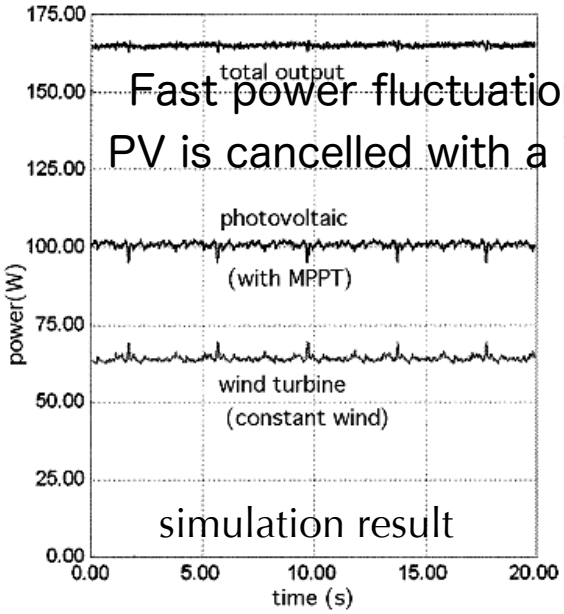
independent operating voltage

more difficult conditions with fewer sensors

Hybridization of generators



PV-WTG hybrid system



Fast power fluctuation of PV is cancelled with a WTG

simulation result