Optimal Space of Dual-axis Trackers for Concentrating Photovoltaic Systems

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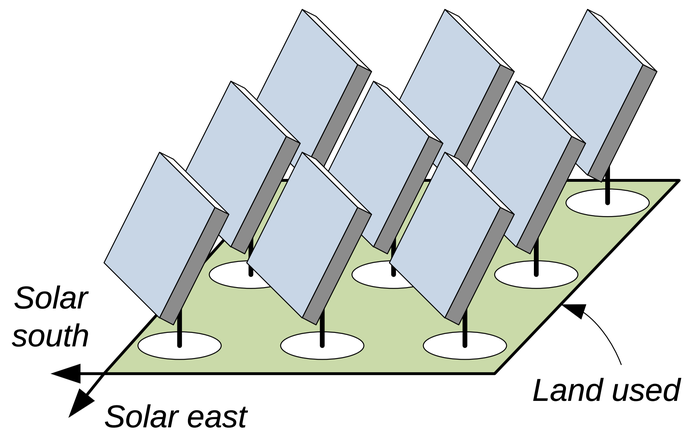
Abstract

The levelized cost of energy (LCOE) is widely used to compare the cost of energy generation across technologies. In a utility-scale concentrating photovoltaic (CPV) system, spacing dual-axis trackers must be balanced with total energy harvested from modules to minimize LCOE. In this paper, a spacing method of dual-axis trackers in a CPV system is presented. Based on definition of LCOE, a cost function is defined and optimized in terms of spacing related parameters. Various methods to estimate hourly direct normal irradiance (DNI) are investigated and *m*-by-*n* tracker array configuration to minimize the cost function are discussed.

Motivation

- Model CPV systems with dual-axis trackers
- Model accurate direct normal irradiation
- Model self-shading loss
- Find the function to reach the optimum solution
- Find optimal spacing of a tracker array
- Expend modeling to *m*-by-*n* tracker array



Cost Function

- Defined as

$$Capacity\ Factor\ (CF) = \frac{\int_{t_1}^{t_2} P(t)dt}{(t_2 - t_1)P_{max}}$$

$$Ground\ Coverage\ Ratio\ (GCR) = \frac{\sum A_{Module}}{A_{land}}$$

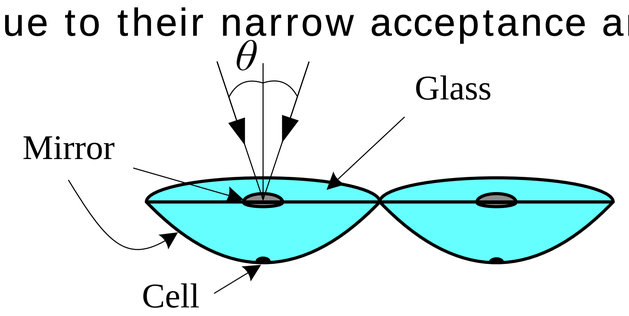
$$LCOE = \frac{\sum C}{\int_{t_1}^{t_2} P(t)dt} = \frac{\sum(C_{others} + C_{land} A_{land})}{CF(t_2 - t_1)P_{max}}$$

$$\propto \boxed{\frac{1 + k/GCR}{CF} = Cost\ Function}$$

- If GCR increases, CF decreases and vice versa.
- In order to minimize LCOE, minimizing the cost function at a given *k* required.
- *k* is a constant independent on time and location.

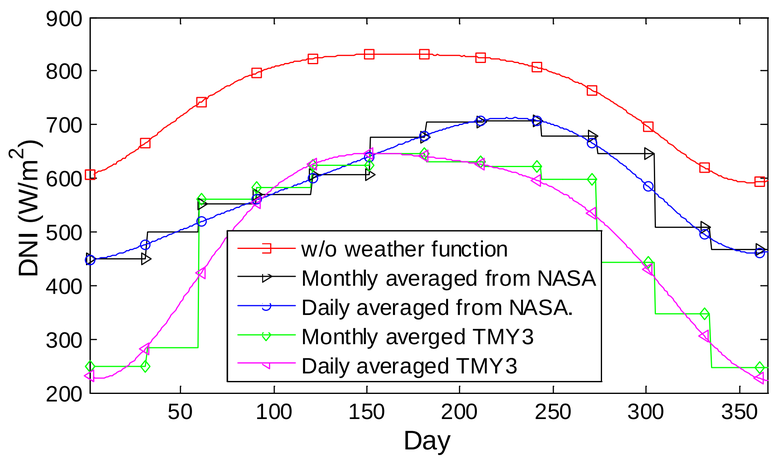
Direct Normal Irradiance (DNI)

- Highly concentrating PV systems accepts only direct normal irradiation due to their narrow acceptance angle



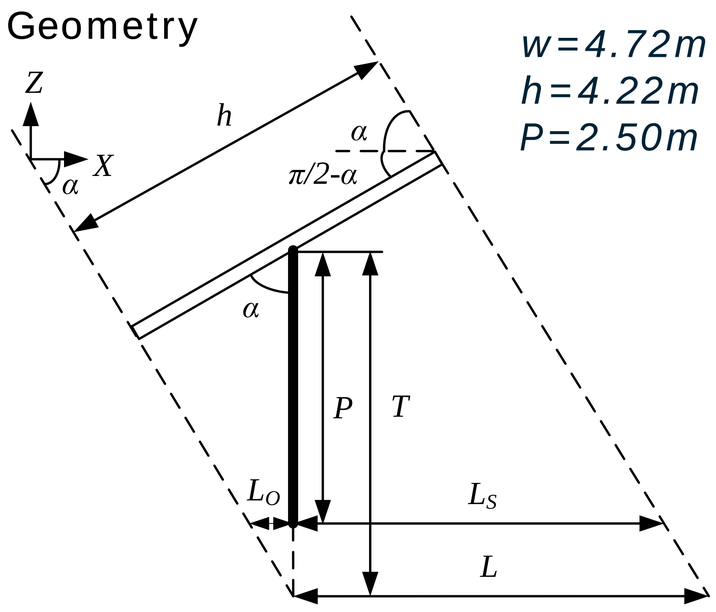
- Method to estimate DNI
  - $I_E(n)$: extraterrestrial radiation
  - $W(n)$: weather function
  - AM: air mass, α: elevation angle

$$I_D(n,\alpha) = I_E(n)W(n)0.7^{AM(\alpha)^{0.678}}$$

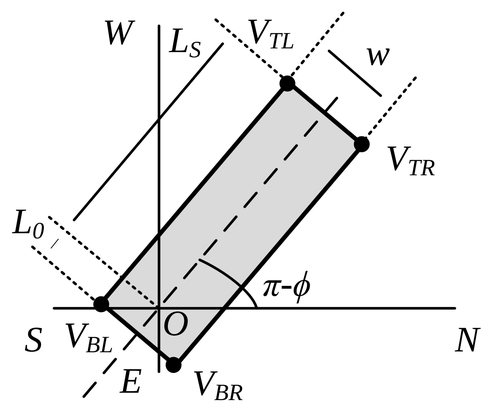


Dual-axis Tracker

- Geometry

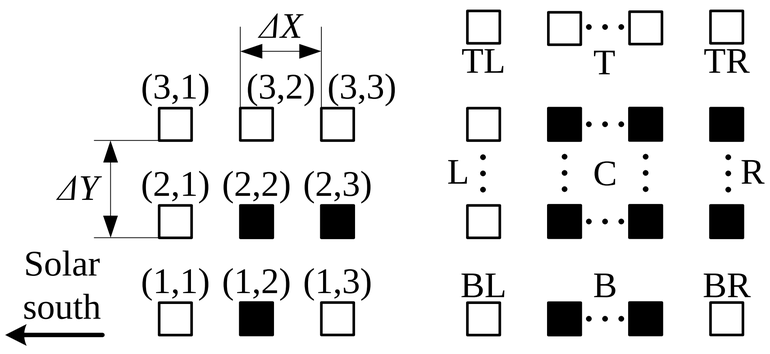


- Shadow by a dual-axis tracker



Shadow by a Tracker Array

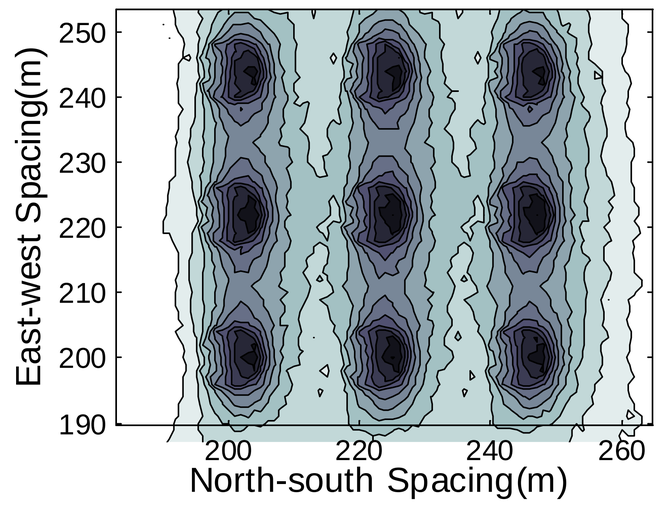
- *m*-by-*n* tracker array
  - Control: ΔX and ΔY
  - Mapping: *m*-by-*n* by 3-by-3 array
- Mapping method



- Variables of a tracker array
  - North-south spacing: ΔX
  - East-west spacing: ΔY
  - Geometry of trackers
  - Geometry of CPV modules

Simulation Results

- Shading by a tracker array
  - Darker color indicates more frequent shading



- Minimum cost function according to *k*