A Rapid Feasibility Checking for Reconfiguration of Mismatched PV Arrays

Dafang Zhao, Fukohito Ooshita, and Michiko Inoue

Nara Institute of Science and Technology (NAIST)

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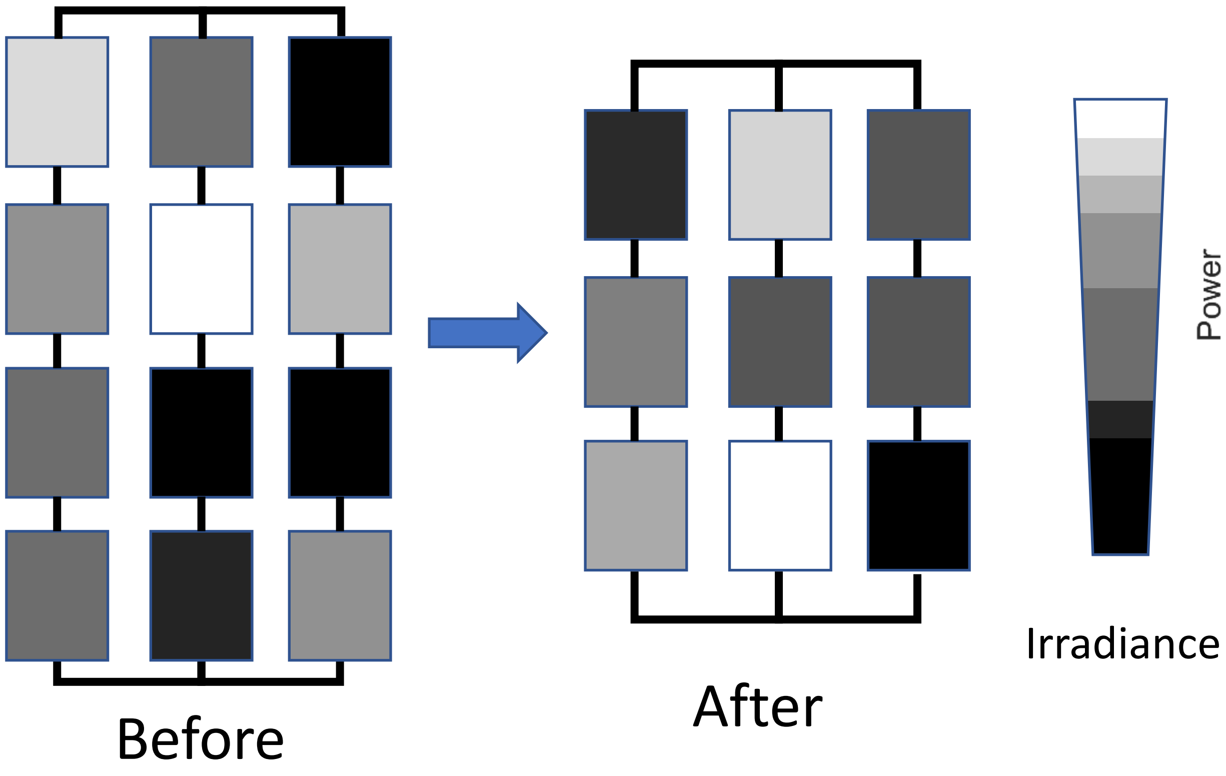
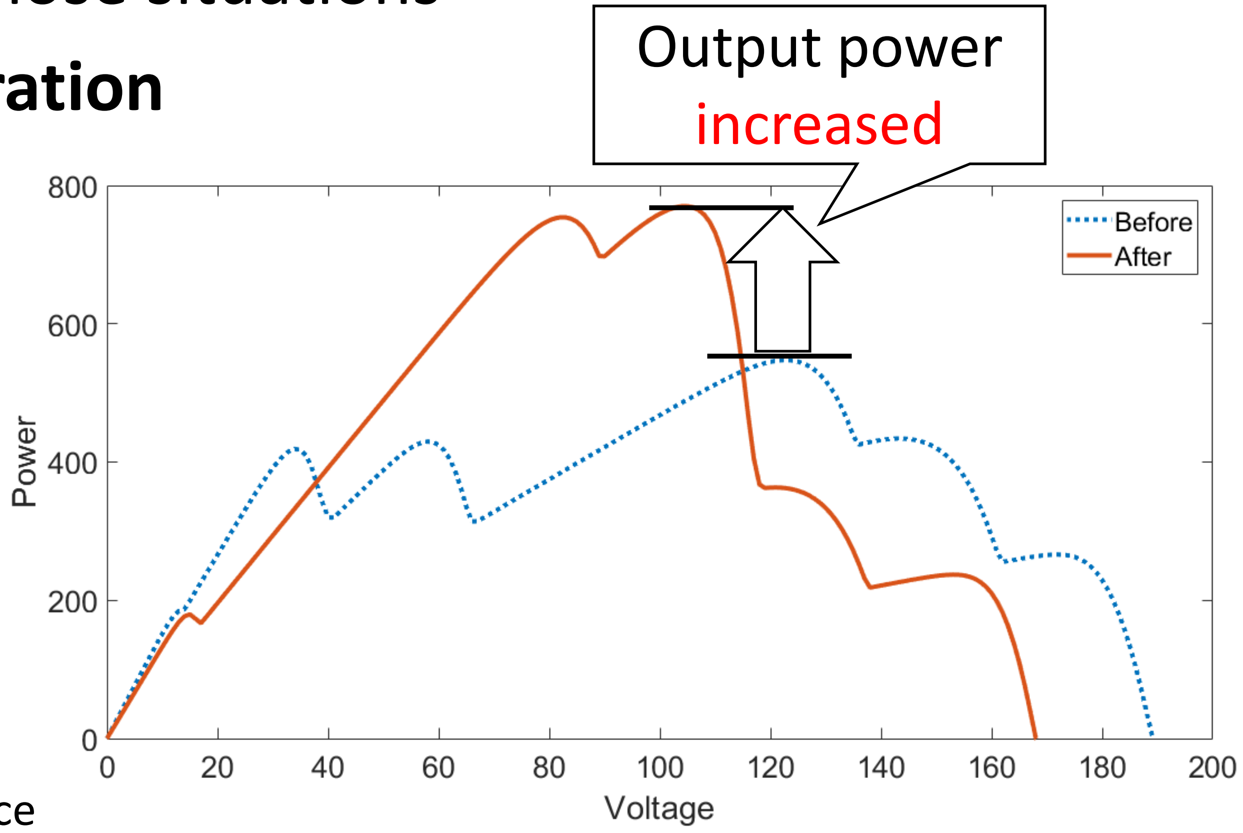
Reconfiguration of mismatched PV array

Mismatched configurations causes energy losses of PV array

PV reconfiguration is one solution for those situations

Challenge: Finding an optimal configuration





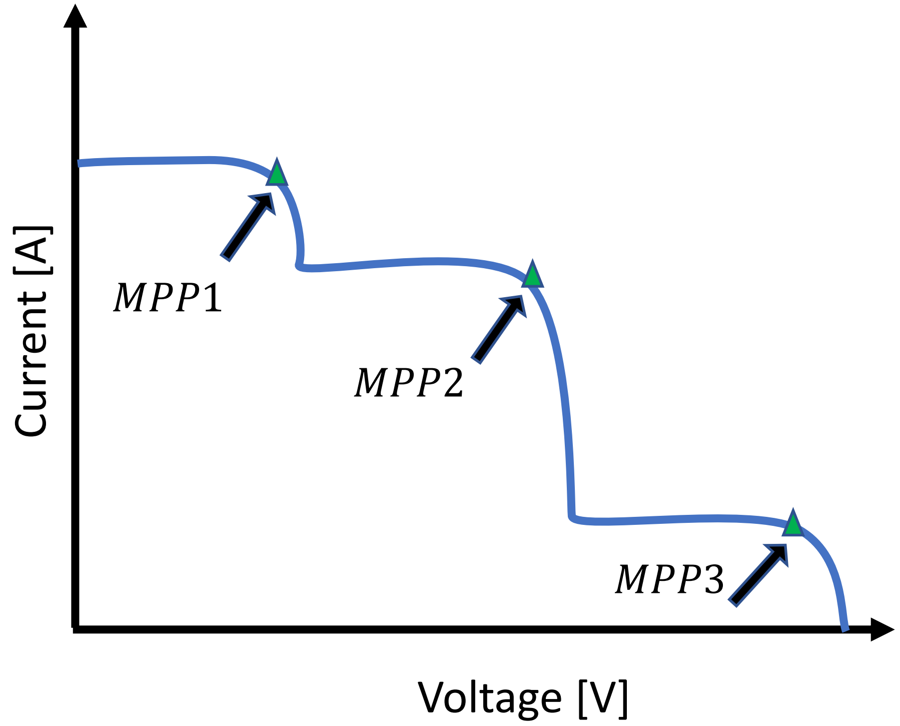
Related works

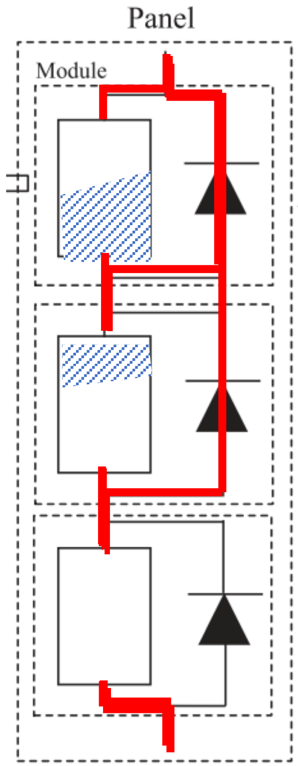
- Estimation of MPPs in PV arrays [1]
  - Estimate power without power simulation
- Fast PV reconfiguration[2]
  - Enumerate candidates of optimal configurations

[1]Orozco-Gutierrez, M. L., et al. "Fast estimation of MPPs in mismatched PV arrays based on lossless model." 2015 International Conference on Clean Electrical Power (ICCEP). IEEE, 2015.
[2]Orozco-Gutierrez, M. L., et al. "Optimized configuration of mismatched photovoltaic arrays." IEEE J. Photovolt 6.5 (2016): 1210-1220

Estimate MPPs in mismatched PV arrays[1]

- Estimate MPPs with current levels and # of active modules
  - MPP voltages are approximated by multiples of # of active modules





	Current	Voltage	# of active modules	Power
MPP1	3.0A	20V	1	60W
MPP2	2.5A	40V	2	100W
MPP3	0.5A	60V	3	30W

[1]Orozco-Gutierrez, M. L., et al. "Fast estimation of MPPs in mismatched PV arrays based on lossless model." 2015 International Conference on Clean Electrical Power (ICCEP). IEEE, 2015.

Fast PV reconfiguration[2]

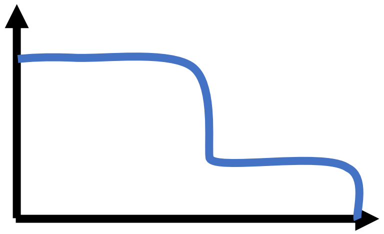
1. Reduce search space
2. Create approximated power matrix
3. Select configuration candidates

[2]Orozco-Gutierrez, M. L., et al. "Optimized configuration of mismatched photovoltaic arrays." IEEE J. Photovolt 6.5 (2016): 1210-1220

Orozco-Gutierrez’s work

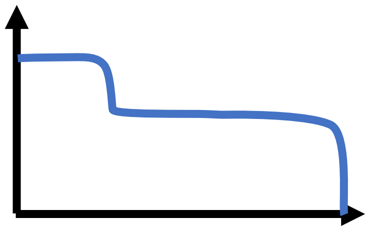
1. Reduce search space
   - Close current values are grouped

(0.48A,0.5A,2.54A, 2.47A, 1.53A,1.55A, 3.0A, 3.1A) → (0.5A,1.5A, 2.5A ,3.0A)

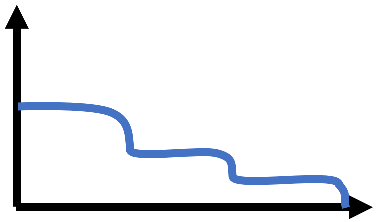


Panel P1

Panel P3



Panel P2

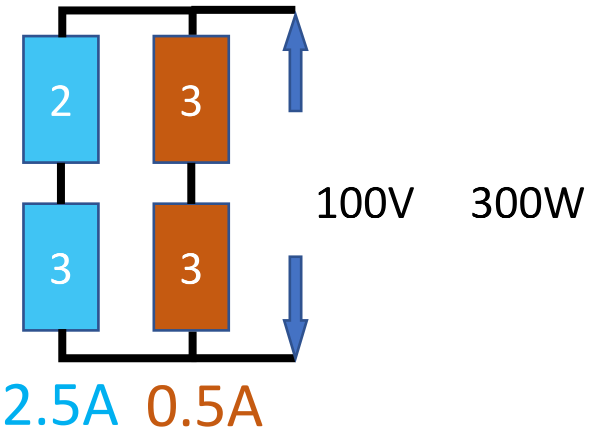


Panel P4

MPP information				
	P1	**P2**	**P3**	**P4**
Impp [A]	**# of active modules**			
3	2	1	0	0
2.5	2	3	0	1
1.5	3	3	0	2
0.5	3	3	3	3

Orozco-Gutierrez's work

2. Create approximated power matrix
3. Select configuration candidates



Approximated Power (W)				
Current(A) → / #of modules ↓ (per−string)	(2.5,0.5)	(2.5,1.5)	(3.0,1.5)	(3.0,2.5)
≥1	60	80	90	110
≥2	120	160	180	220
≥3	180	240	270	330
≥4	240	320	360	440
≥5	300	400	450	550

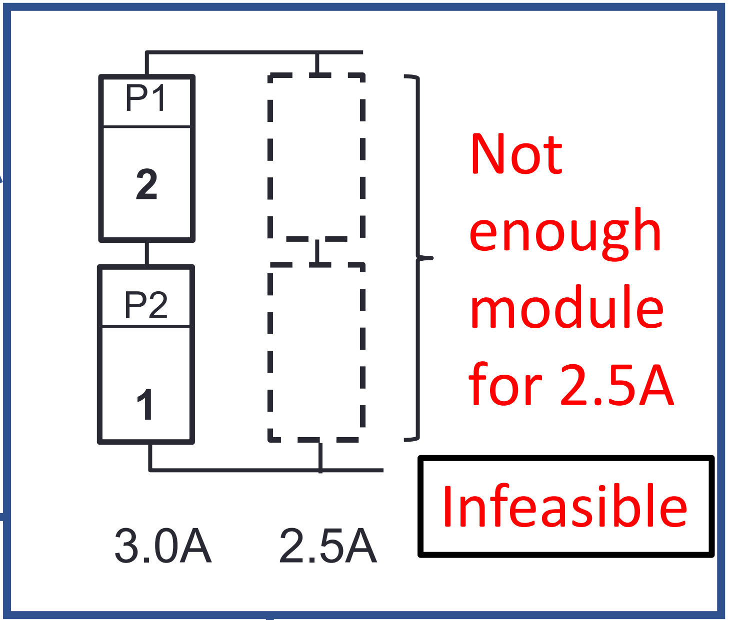
Current(A) → / #of modules ↓ (per−string)	(2.5,0.5)	(2.5,1.5)	(3.0,1.5)	(3.0,2.5)
≥1	60	80	90	110
≥2	120	160	180	220
≥3	180	240	270	**330**
≥4	240	**320**	--	--
≥5	**300***	--	--	--

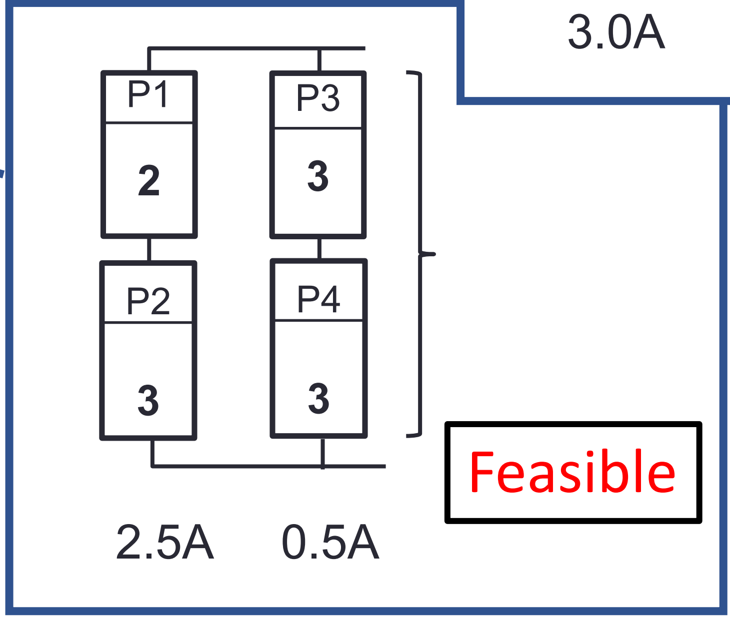
Provided feasibility check method is not sufficient

Example of infeasible configuration

Current(A) → / #of modules ↓ (per−string)	(2.5,0.5)	(2.5,1.5)	(3.0,1.5)	(3.0,2.5)
≥1	60	80	90	110
≥2	120	160	180	220
≥3	180	240	270	330
≥4	240	320	--	--
≥5	300	--	--	--

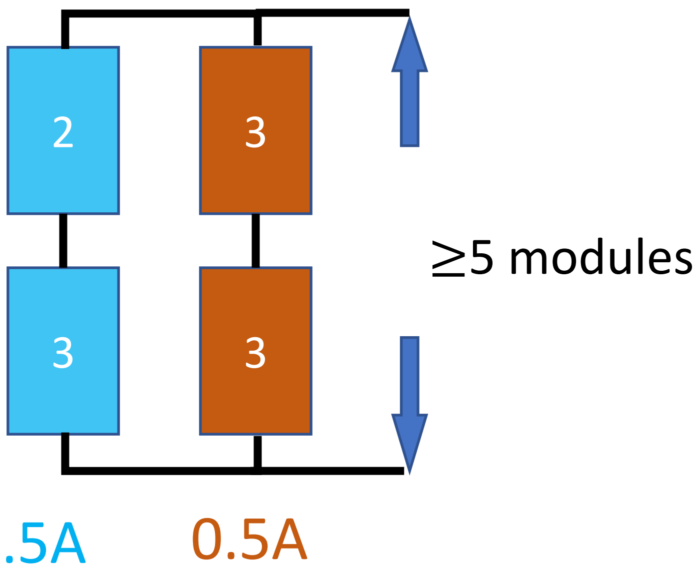
MPP information				
	P1	**P2**	**P3**	**P4**
Impp [A]	**# of active modules**			
3	2	1	0	0
2.5	2	3	0	1
1.5	3	3	0	2
0.5	3	3	3	3





Feasibility problem

- INPUT
  - MPP information
  - Current sequence: ***Q***= $(Q1, Q2, \dots)$
  - The number of active module per-string: ***m***
- OUTPUT
  - Whether *Q* with *m* modules is feasible or not



MPP information				
	P1	**P2**	**P3**	**P4**
Impp [A]	**# of active modules**			
3	2	1	0	0
2.5	2	3	0	1
1.5	3	3	0	2
0.5	3	3	3	3

Current(A) → / #of modules (per−string) ↓	(2.5,0.5)	(2.5,1.5)	(3.0,1.5)	(3.0,2.5)
≥1	60	80	90	110
≥2	120	160	180	220
≥3	180	240	270	NO
≥4	240	NO	--	--
≥5	YES	--	--	--

Proposed algorithm

Choose panels based on their losses

Loss: How many modules can not be active

Example: If P2 is used for Q1, one loss for Q2 $(Loss(\mathrm{P2}, \mathrm{Q2}) = 1)$

If P2 is used for Q2, no loess for Q3 $(Loss(\mathrm{P2}, \mathrm{Q3}) = 0)$

		P 1	P 2	P 3	P 4	P 5	P 6	P 7
# of active modules	$Q1$	1	1	1	1	2	2	1
	$Q2$	1	2	2	2	3	3	2
	$Q3$	1	2	2	2	3	3	3
$Loss(\mathrm{panel}, \mathrm{Q2})$		0	1	1	1	1	1	1
$Loss(\mathrm{panel}, \mathrm{Q3})$		0	0	0	0	0	0	1

Current sequence: $Q1 \geq Q2 \geq Q3$

Proposed algorithm

Select panels for strings for $Q1$, $Q2$,…

Step 1: Sort panels in a lexicographically ascending order: Loss

Step 2: Select panels with enough active modules *m*

Step 3: Cancel redundant panels

Step 4: Swap panels to minimize the number of panels

Example:
String for $Q1$
m ≥ 5

	P 1	P 2	P 3	P 4	P 5	P 6	P 7
$M_p(Q1)$	1	1	1	1	2	2	1
$M_p(Q2)$	1	2	2	2	3	3	2
$M_p(Q3)$	1	2	2	2	3	3	3
$Loss(p,2)$	0	1	1	1	1	1	1
$Loss(p,3)$	0	0	0	0	0	0	1
Step 2	√	√	√	√	√		
Step 3	√	√	√		√		
Step 4	√				√	√	

Experiment Results

- 100 mismatched PV arrays
  - 6 – 24 panels, 3 – 8 strings
- Shading condition: random distribution

	Proposed	Exhaustive search
# of arrays	100	
Total # of candidates	486	
# of feasible candidates	324	327
# of infeasible candidates	162	159
Error rate	0.62%	---
Ave. times per array	3.6ms	98000ms

0.62% of error, 27,000 times faster

Summary

- A rapid feasibility checking method is proposed
- 27000 times faster than exhaustive search
- Error rate less than 1%