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# **A novel PV sub-module-level power-balancing topology for MPPT under partial shading and mismatch conditions**

**Key words:** Sub-module-level MPPT, Differential power processing (DPP), Distributed power converters, Switched-capacitor (SC) converters

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# Motivation/Main ideas

## Motivation

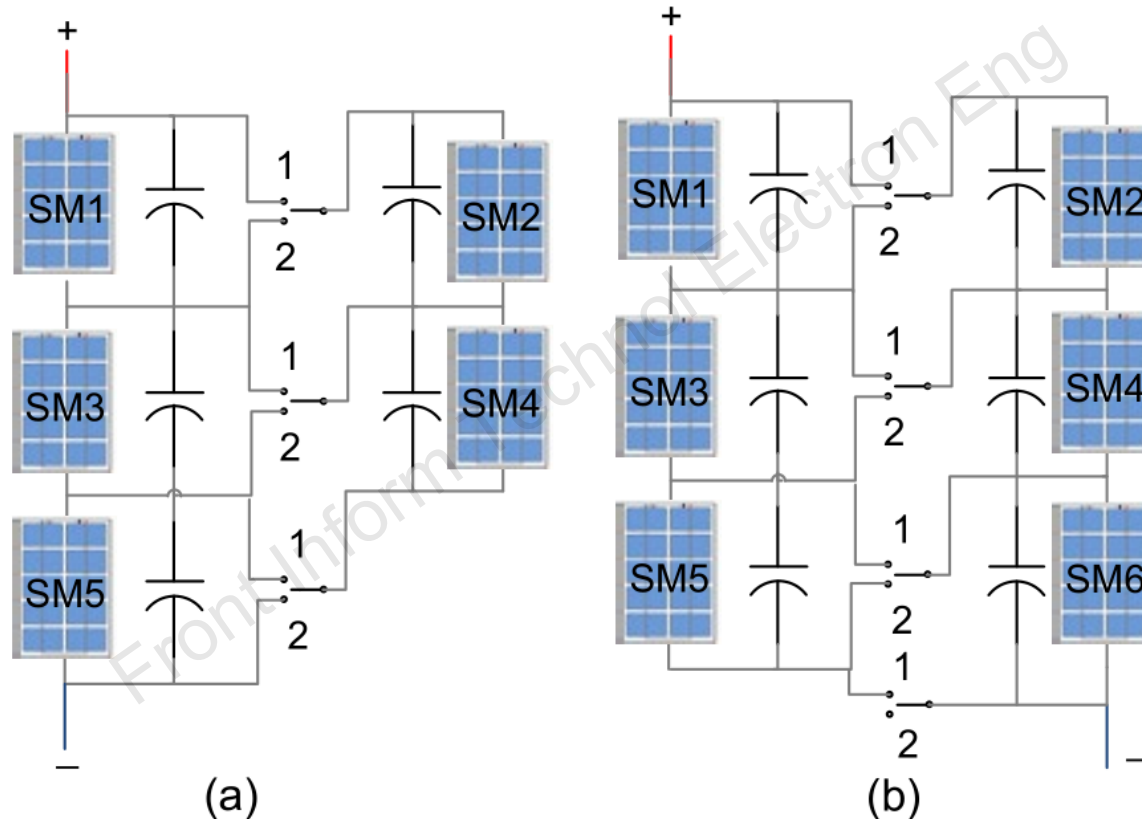
Partial shading and mismatch conditions among the series-connected modules/sub-modules suffer from a nonconvex power curve with multiple local maxima and decreased peak power for the whole string.

## Main ideas

Energy transfer between the sub-modules brings them to the same operating voltage, and this collective operation produces a convex power curve, which results in increased peak power for the string.

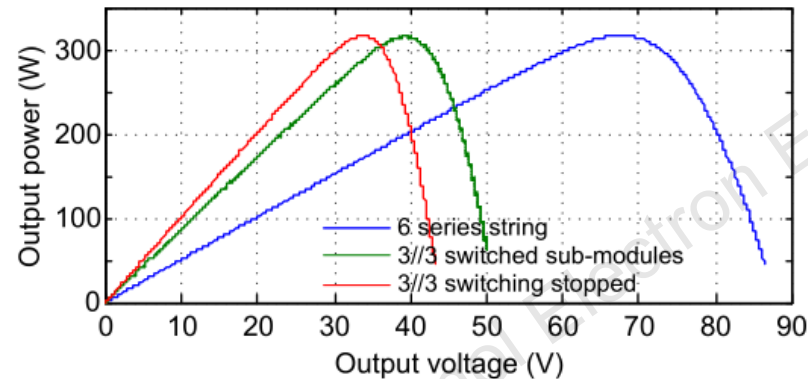
# Method

- Use switched capacitor converter to transfer energy between sub-modules to obtain convex power curves with increased peak value.

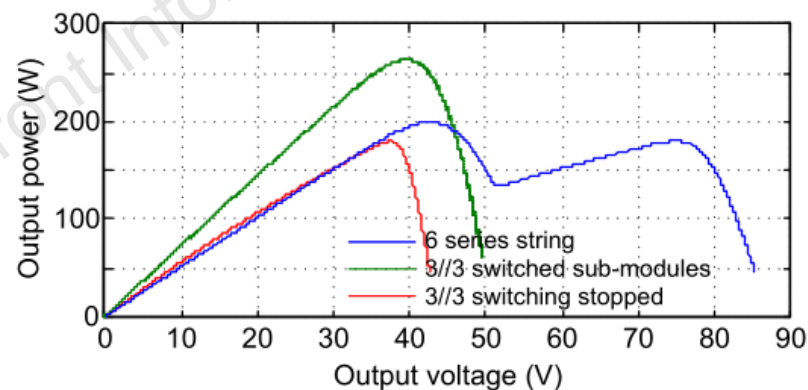


**Fig. 1** Proposed ladder-connected sub-modules (SMs) topology that requires continuous switching (a) and allows stopping the switching process (b)

# Major results (I)



**Fig. 4 Comparisons of power versus output voltage (P-V) curves for uniform irradiation conditions (references to color refer to the online version of this figure)**



**Fig. 5 Comparisons of power versus output voltage (P-V) curves for partially shaded condition (references to color refer to the online version of this figure)**

# Major results (II)

**Table 1 Comparison for maximum powers and efficiencies in simulations**

| Configuration      | Maximum power (W) |        | CE (%) | EPE (%) |
|--------------------|-------------------|--------|--------|---------|
|                    | UR                | 16% OS |        |         |
| 6 series+by-pass   | 318.06            | 199.47 | 100    | 62.71   |
| 3//3 sw stopped    | 317.55            | 179.98 | 99.84  | 56.67   |
| 3//3 sw sub-module | 316.41            | 264.18 | 99.48  | 83.49   |

UR: uniform radiation; OS: overall shading; CE: conversion efficiency; EPE: extracted power efficiency

# Conclusions

- The switching process between the SMs enables the array to act as a single ideal PV module.
- The parallel-ladder configuration of the SMs requires  $n$  capacitors and  $n+1$  switches for the power balancing of  $n$  SMs, while the switched capacitor topology proposed by the similar literature.
- This advantage results in reduced power electronics losses, less cost, and smaller size of the converter circuit.
- The results proved that, with the proposed topology, it is possible to extract almost all the power available on the partially shaded string and transfer it to the load side.