GOALI Report Section on: Topology Reconfiguration for Optimization of Photovoltaic Array Output

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This section of the GOALI report describes the method used to find the optimal array topology under partial shading conditions. An ideal PV array connected in any topology performs identically. When faults occur in the array, however, the performance of each of the topologies differs and the default array topology may not produce the maximum yield. In this section, a topology reconfiguration method is proposed to predict the optimal topology for a photovoltaic array consisting of shaded modules. This method assumes that the PV system is provided with an array reconfiguration facility. The topology reconfiguration method can be implemented in monitoring systems to predict the best suitable array configuration for a definite time period using the previous array's measurements.

The topology reconfiguration method is described in the block diagram shown in Fig. 1. The operation of the system is explained below.

1 Fault Detection Algorithm

A monitoring system provides the plane of array (POA) irradiance and the module level measurements: the maximum power point voltage (V_{MP}), maximum power point current (I_{MP}), module temperature and the aging information, which can be used to detect faults using the fault detection algorithms. In general, the faulty modules form a cluster in the I-V space, while the rest of the string in which the fault occurs forms another cluster, and the remaining unaffected modules in the string form a third cluster. One such algorithm to detect the shaded modules is explained in [1, 2].

2 Feasible Configurations

The information from the fault detection algorithms is also used to find the feasible topology/topologies. For example in the case of shading, the faulty

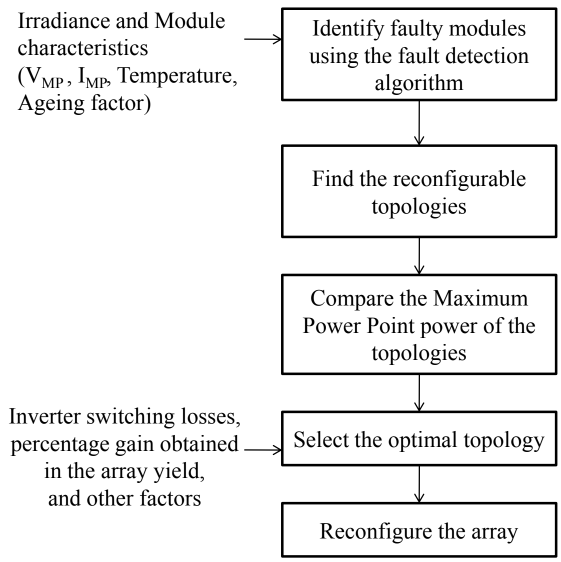

Figure 1: Block diagram explaining the topology reconfiguration method.

modules can be bypassed based on the intensity of shading. A new configuration is obtained by bypassing the shaded modules. This topology can also be reconfigured by evenly distributing the modules into a row-column array resulting in another topology. Therefore SP, BL, TCT, and the bypassed and reconfigured (BR) topologies constitute the feasible configurations.

3 Performance of the Topologies

Once the feasible configurations are determined, their performance can be predicted using any of several PV performance models [3, 4]. For example, the direct current (DC) power generated by a topology can be determined for a given irradiance (W/m^2) and module temperature ($^\circ C$) using the UW-Madison model in a circuit simulator such as SPICE. The maximum power point (MPPT) power can be used as a performance metric to compare the topologies. The MPPT power is expressed as a percentage power obtained with respect to the array power under ideal (no fault) conditions.

4 Additional Considerations for Optimization

Several factors beyond simulated MPPT power affect the decision to switch array topology. Most notably, switching losses reduce the effectiveness of the algorithm. This occurs because the IEEE 1547 standard [5] mandates a fiveminute shutdown following any out-of-bounds condition. Rapid restart is limited by standards compliance rather than technical challenges; some non-grid-interacting inverters [6, 7] feature an automatic restart function following power interruption. Note that this switching delay is caused entirely by the inverter; the optimization algorithm itself only simulates a small number of feasible configurations and does not require significant time or computational resources to run. The current version is not optimized for runtime in any way and requires less than 3 seconds to run on a desktop computer.

The simulation results that follow in consider only MPPT power on the DC side of the inverter to determine the optimal topology. Inverter downtime, resistive wiring losses, and variable AC/DC conversion efficiency are not considered. Of these effects, only inverter down time is likely to significantly impact results. The authors are currently studying the prediction of future irradiance at the module level, with the goal of providing an optimal decision on when to perform reconfiguration.

References

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