

Extremum Seeking MPPT Against Commercial Power Optimizers

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Opis teme

Every solar panel in a real installation is different from its neighbours at any given moment. Dust, partial shadow, aging, and temperature gradients all cause individual panels to produce less than their rated peak, and by different amounts at the same time. Getting the maximum available power out of the array as a whole is a harder problem than it looks.

Commercial optimizers usually rely on per-panel MPPT loops, such as Perturb and Observe approaches, where each optimizer tracks only its own panel and adjusts its duty cycle without knowledge of neighboring panels. In a series-connected string, all converters share the same dc bus current, so changes in one converter can affect the whole string. This creates coupling, unpredictable transient behavior, and condition-dependent convergence during partial shading, temperature changes, and module mismatch.

Extremum Seeking (ES) is a model-free real-time optimization technique that does not require knowledge of the power surface. A multivariable ES design treats the entire panel array as a single optimization problem, moving all duty cycles together toward the global maximum power point. Newton-based ES additionally estimates the Hessian, making convergence rate user-assignable and less dependent on irradiance, temperature, or shading conditions.

The project asks whether this theoretical advantage holds up on real hardware. The project has access to physical Luxor ECO LINE HALF CELL monocrystalline panels, including 440-460 W and 540-560 W variants, and infrastructure for controlled experiments such as partial shading, step irradiance changes, and module mismatch.

Commercial optimizer specifications and measured field data from SolarEdge, Tigo, and Huawei installations serve as the benchmark.

Zadaci i ciljevi

The student researcher works on both components of the project with the mentor.

The first component is algorithm implementation and hardware experiments. The student implements a Newton-based or gradient-based ES MPPT algorithm on a dc/dc converter stage connected to physical Luxor panels. Working from the theoretical framework in the control literature, the student translates the algorithm into a microcontroller-ready implementation, tunes probing frequencies and filter parameters, and runs structured experiments involving partial shading, step changes in irradiance, module mismatch, and temperature variation.

The second component is benchmarking against commercial optimizers. SolarEdge, Tigo, and Huawei use different architectural approaches, including string inverters with per-panel optimizers, partial optimization of shaded panels only, and MBUS communication over dc cables. The student characterizes these systems using published datasheets, manufacturer documentation, and measured power quality diagrams from field installations.

The goal is a fair and reproducible comparison based on convergence time to maximum power point, steady-state error, transient behavior under partial shading step changes, and hardware cost per watt recovered. The expected outcome is a working hardware implementation, reproducible experimental results, and a clear answer to the comparison question.

Tražene vještine od studenata

This project is open to Bachelor and Master students with a background in electrical engineering, power electronics, or control systems. Experience with microcontrollers or embedded C is helpful but not required.

Familiarity with basic circuit analysis and dc/dc converter operation is expected.

Some exposure to control theory, including transfer functions and feedback loops, is useful.

No prior experience with extremum seeking or MPPT is required.

Comfort working with physical hardware, oscilloscopes, and measurement equipment matters more than simulation experience.

The work alternates between theory, implementation, and measurement. Progress is defined by what the hardware does, not what the simulation shows.