
Master project, 2023 – 2024

Artificial Intelligence for Dynamic Programming

Application to optimal design and control of multi-sources electric systems

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Context

When designing an electric system by simultaneous optimization of sizing and control on duty-cycle, we can place ourselves in an ideal case where the future is known and for which no a-priori on the control law is imposed. In this way, the optimal control problem of the system contains a number of decision variables proportional to the number of time steps, which is huge when properly considering intermittent renewable sources such as photovoltaic panels and wind turbines with variation of generated power along hours and seasons.

In the literature, this topic is known as plant/controller optimization. This is a very large topic in system sciences with application in many engineering fields. Among the vast literature, Reyer [1]-[2] and Papalambros [2] propose four strategies for plant/controller optimization (fig. 1). One strategy, called bi-level, is very effective for complex non-linear system optimization and uses two optimization loops: The outer loop optimizes only the plant design while the inner (nested) loop generates the optimal control for each plant selected by the outer loop.

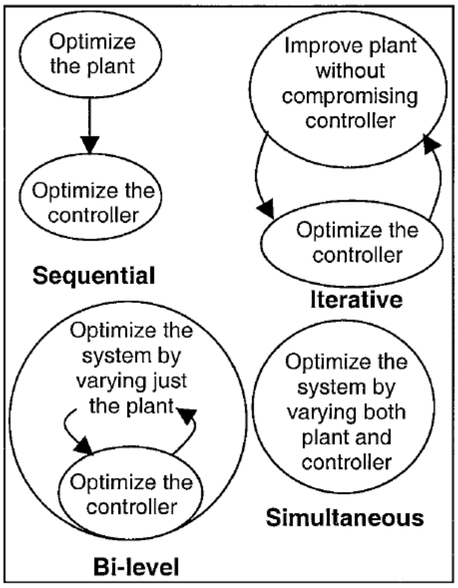

Fig. 1: Strategies for Plant/Controller Optimization [2]

The success of this strategy relies on the performance of the algorithm used to solve the inner loop optimization: It should be fast and accurate, even for a large time range. Most non-linear optimization algorithms suffer from the so-called "curse of dimensionality" making them not suitable for this purpose as their computing time is exponentially proportional to the number of decision variables.

Based on Bellman's principle [3], the dynamic programming [4] offers the advantage of a computing time that is linearly proportional to the number of time steps. However, the discretization of state and control variables, intrinsic to this algorithm, leads to a loss of precision or an unaffordable computing time (exponential variation) despite efforts made to reduced time and memory requirement [5].

Objective

The main objectives of the master project are to increase the accuracy and reduce the computing time of the dynamic programming, making it suitable for optimal design of renewable energy systems.
The case study of a house with photovoltaic panel and energy storage system will be used to highlight the inaccuracies of Sundström's dynamic programming algorithm. After introducing artificial intelligence in the algorithm, the perfomances of the improved algorithm will be assessed on the test-case.

Work steps

1 Bibliography on the optimal energy management of electric system with renewable energies and energy storage systems
2 Deep understanding of Bellman's principle and dynamic programming
3 Test dynamic programming on the solar house test-case and highlight difficulties and inaccuracies
4 Improve dynamic programming by using artificial intelligence
5 Propose other ways of improvement and test them

Keyword

multi-sources electric systems, complex systems, optimal control, dynamic programming, artificial intelligence, plant/controller optimization

References

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