Machine learning aided optimal design of power electronic systems

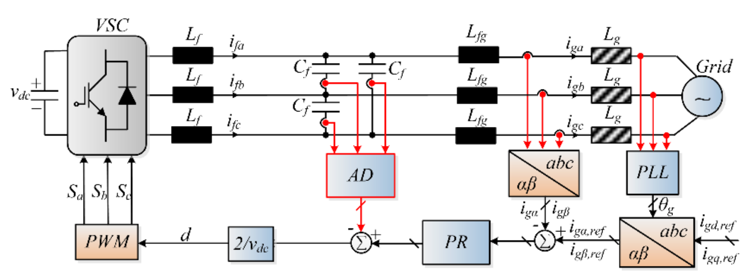
Proposal for the PED3 autumn 2018: Power Electronics and Drives

Background

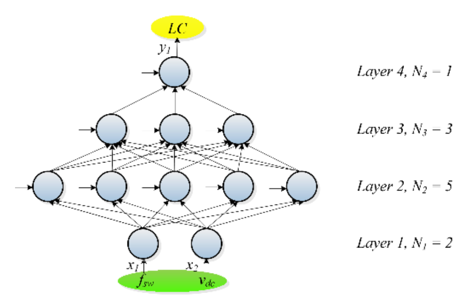
Machine learning became mainstream at around 2016. For the first time in history, machine learning at that time became not only available to big companies like Google, Amazon or Apple, but also to numerous startups that have started developing products and services using machine learning. Today, anyone with access to personal computer and mainstream software like MATLAB can implement his own machine learning algorithms.

But first of all, what is machine learning? Machine learning is essentially an automated construction of the model of some system entirely from input/output data recorded from that system. In principle, it is not needed to know any properties of the given system, but the selected machine learning algorithm makes the machine (e.g. our personal computer) learn the characteristics of the system from the input/output data we have. The key characteristic of the model developed in this way is that it can be executed several orders of magnitude faster than the real system (or a detailed model of the real system) yet keep the arbitrary accuracy.

Over the last couple of years, very effective machine learning tools have been developed that can be used for practically everything. For example, these tools can enable a junior programmer to build amazing things in a very fast way. We can now easily use machine learning for things like speech and facial recognition, language translation, data classification and object detection. Many tasks that previously could only be done manually, can be automated today using machine learning.



a) Inverter – detailed model



b) Inverter – surrogate model

Fig. 1. Comparison between the detailed (very slow) and surrogate model (fast and accurate) of the power electronic inverter.

Besides the aforementioned domains, system design optimization is another key application area of machine learning. This approach is particularly useful in complex, non-convex optimization problems, where classical optimization routines entail a risk of getting stuck in the local optima, whereas the heuristic algorithms cannot guarantee the optimality. Grid-connected power converters are excellent examples of such complex systems, as there are numerous parameters that affect the performance, reliability and cost-effectiveness of the system.

The key idea of machine-learning based optimization is to create fast and accurate surrogate model of the system (e.g. see Fig. 1 (a) for example of the detailed scheme of grid-connected power converter and its corresponding surrogate model based on the artificial neural network that is a special type of machine learning algorithm in Fig. 1 (b)). As mentioned before, the surrogate model behaves essentially as the detailed one but can be executed many orders of magnitude faster. Therefore, we can quickly and effectively search through the design space. In many cases, the optimal design parameters can be found on very complex system in a very short time, and without any risk to get stuck in the local optima.

Objectives

The objective of this project is to introduce the students with the fundamental ideas behind machine learning, with special emphasis on artificial neural networks. Case study of the grid connected power converter will be investigated in detail and the optimal design will be carried out using the machine learning methodology.

Students will develop following skills

- Understand the main principles of machine learning
- Being able to create data from the model of the power electronic system
- Learn how to train the machine learning algorithm and build a surrogate model of the system
- Use the surrogate model of the system for fast and effective optimal design
- Test the optimal design on the experimental test setup (see Fig. 2)
- Receive training for preparing scientific publication

Fig. 2. Laboratory test setup available for validation of the optimal power electronic system design.

Resources

- Matlab/Simulink, Matlab/Machine Learning toolbox, and Matlab/Parallel Computing toolbox
- Multi-core workstation for performing concurrent simulations of power electronic systems
- Practical laboratory test setup to validate the optimized design in the laboratory (see Fig. 2)

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Key reference

T. Dragičević, P. Wheeler, and F. Blaabjerg "Machine learning aided automated design for reliability of power electronic systems," IEEE Trans. Power Electron., conditionally accepted for publication (2018). (available as per request)