Condition Monitoring of Power Electronic Systems Through Data Analysis of Measurement Signals and Control Output Variables

* Explores software-based machine learning methods
* Focus on DC-link capacitors and semiconductor devices
* “ Condition monitoring is a monitoring concept that aims to detect the condition of a system during operation and, thus, provide early information for necessary repair and maintenance work. The information provided by condition monitoring enables the selection of optimal maintenance intervals and the reduction of downtimes of the system”
* 3 principles of condition monitoring
  + Monitoring of Degradation Indicators: physical measurement circuits (direct) or model estimations (indirect)
  + Aging-Based Modeling: models a specific aging mechanism that leads to converter failure (ex: thermomechanical and electrochemical models)
  + Software-Based Methods: machine learning algorithms
    - References particle swarm optimization algorithm from *A Digital Twin Based Estimation Method for Health Indicators of DC–DC Converters* paper
* This paper does not rely on a “digital twin” per se
  + It trains models with actual data to create something to compare the collected data sets to
* Anomaly detection phase -> identifies an issue
* Root cause phase -> identifies what the cause of the failure is not just that it fails
* SECTION III.B - degradation indicators for dc-link capacitors (C and ESR)
  + For electrolytic capacitors, the degradation limit is reached when the ESR doubles [14]
* SECTION IV.A - Ideal state-space equations
* SECTION IV.B - Introduces modified equations for

Condition Monitoring of Power Electronics Converters Based on Digital Twin

* “Moreover, methods mentioned above all use an ‘average model’ to characterize the basic operation of the system, which cannot show the PWM switching frequency component in the output voltage. To overcome this issue, a digital-twin-based method has been proposed in [8]. The digital twin aims to create a replica of physical converter by constantly adjusting its parameters through the algorithm to minimize difference between the waveforms of the physical converter and that of the digital counterpart.”
* Process is based on time domain meaning it avoids mathematical modeling and linearization so that no extra signal is needed and the error could be further reduced.
* needs a small amount of sampled data in one single switching period under steady state, making it simpler and quicker.
* objective parameters include the parasitic resistances RS, RL, RC of switch, inductor, capacitor, the inductance L, the capacitance C and the load resistance R.
* Simulation layer
  + Actual simulation of the waveforms (basically what we’ve done with our state space equations)
* Computation layer
  + The objective function updates parameters to make the simulation more accurate to the actual data
* Helpful data: Based on previous studies, the values of key components in a converter such as capacitance may drop by 5%-20% and the values of their parasitic resistances would increase by 20%-40% after a long-term operation
* This paper uses 10 points from the simulation and the sampled data to input into the objective function. This function gives the best accurate result to model the real values changes the parameters for the model to make the digital twin more accurate. This doesn’t help us identify failure.

*A Digital Twin Based Estimation Method for Health Indicators of DC–DC Converters* paper

* Explains iL and Vc are the health indicators of a DC-DC converter
* Capacitor Degradation Monitoring (C and ESR impact the capacitor health)
* “Specifically, the estimated medians of C and Rc are decreased by 9.7% and increased by 21%, respectively, when the capacitor is degraded by 8.8%.”
* practical considerations are discussed (impact of sam-pling rate, different operation conditions, temperature and the uncertainty caused by errors).