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DC-link capacitors diagnostics

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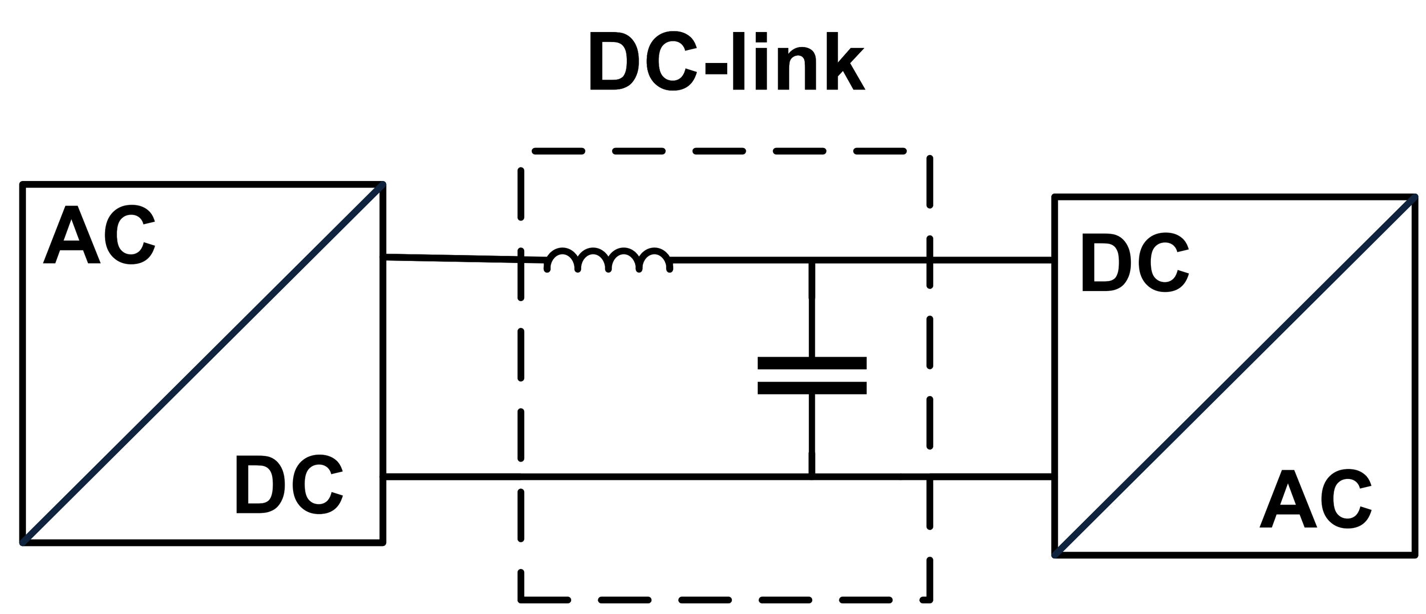


In the **future hybrid-electric airplanes**, power to the electrical propulsion will be transferred via converters in order to obtain desired electrical motor operations parameters. Between the generator rectifier and the propulsion inverter, DC-link is present. That component is crucial to reduce voltage ripples that may cause decrease in quality of power provided to the electrical motor. The **DC-link capacitance drop** is one of the indicators of capacitor ageing and **should be monitored**. Moreover, in the vast diagnostics system of the aircraft – algorithms should be **not complex** and **require small data packs** in order not to overload the data bus.

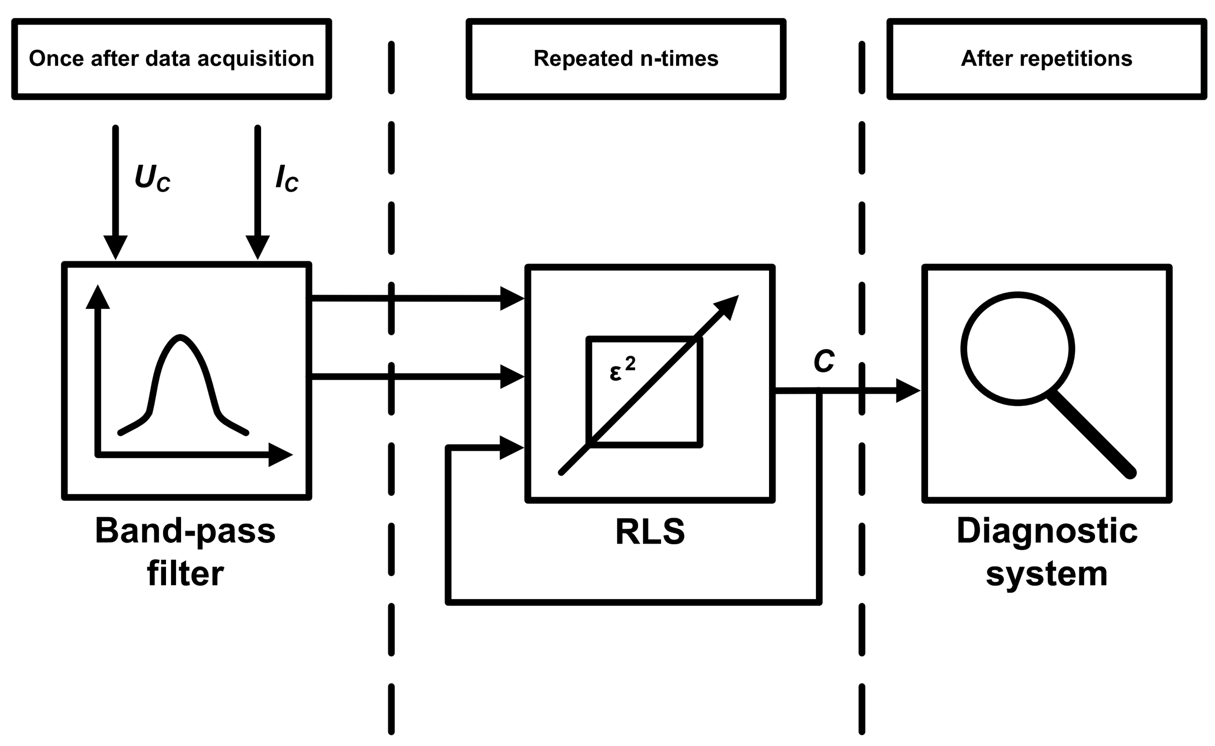
The novel Repetitive Recursive Least Squares (**RRLS**) [1] method utilizes the signal properties for numerical operations simplification and repetitive approach in order to minimize required measurement data size.
The band-pass filtering of the ripple allows for the **capacitor model simplification** from

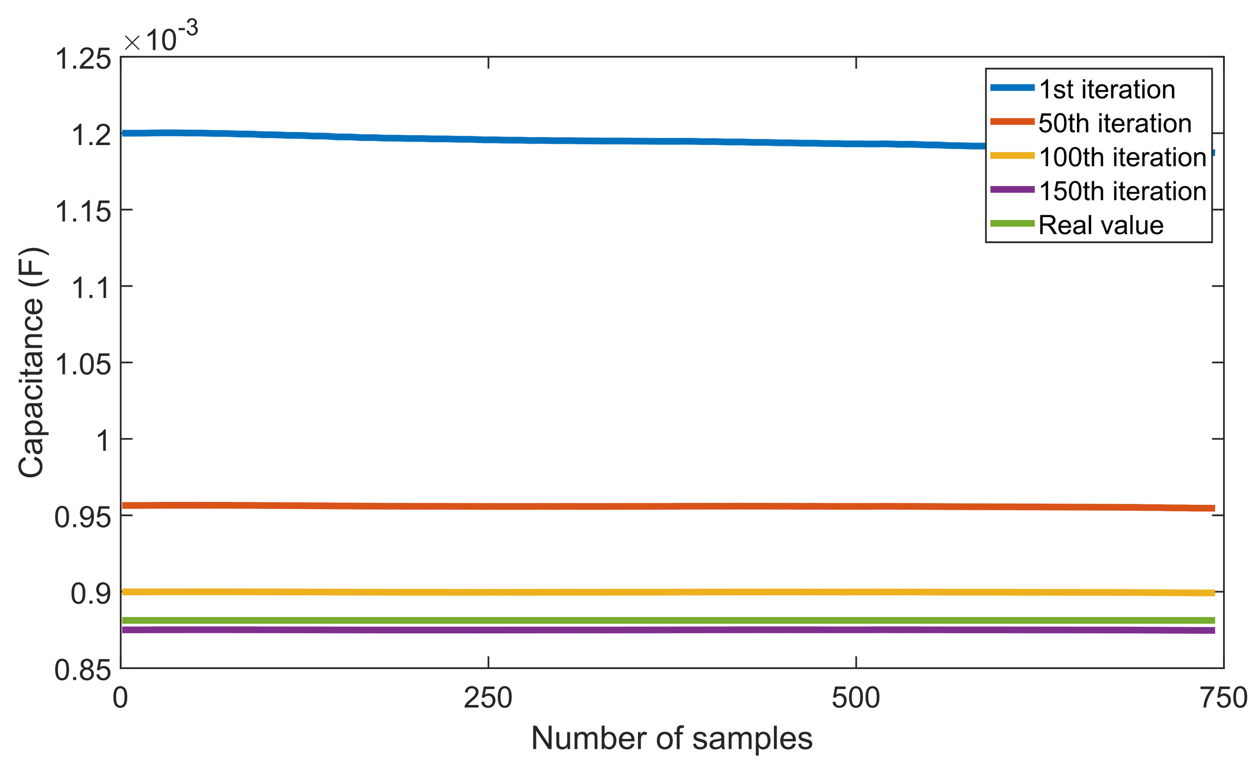
$$U_c(n) = U_c(n-1) + \left(R_q + \frac{T_p}{2C}\right) I_c(n) + \left(\frac{T_p}{2C} - R_q\right) I_c(n-1)$$

to

$$U_c(n) = U_c(n-1) + \frac{T_p}{2C}\left(I_c(n) + I_c(n-1)\right)$$

In this way, only capacitance is estimated – **no matrix operations needed**.

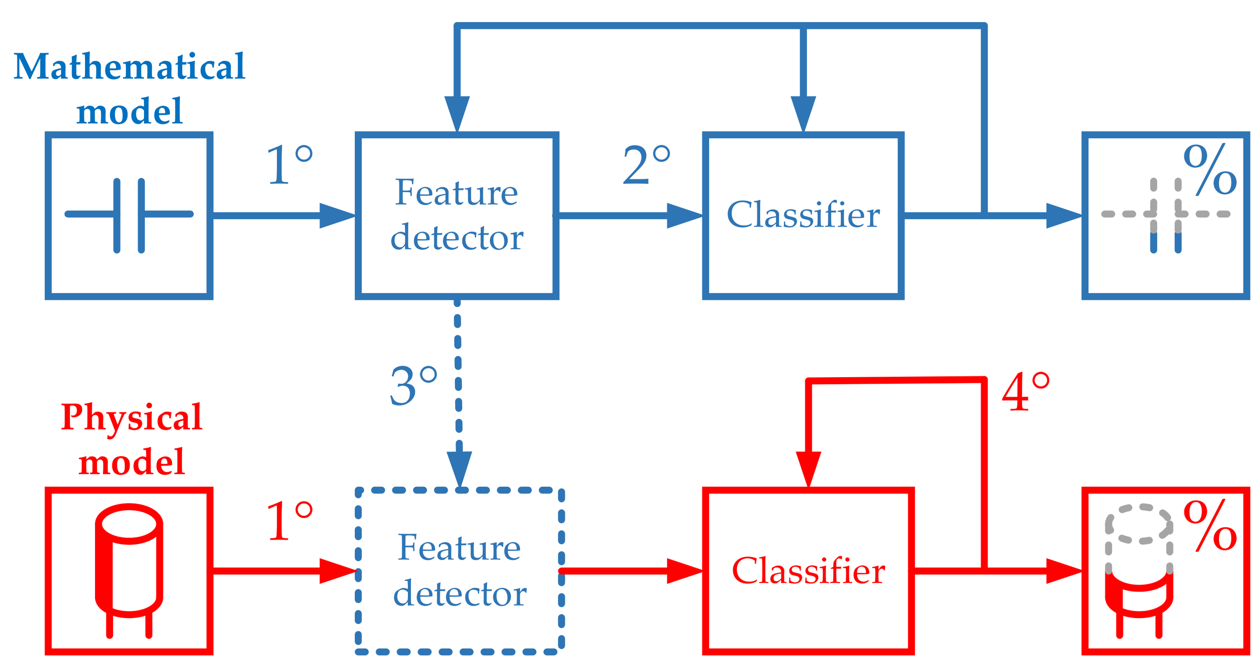




The repetitive nature of the **RRLS** method helps to **minimize required amount of samples** for parameter estimation. The RLS core of the algorithm estimates DC-link capacitance in the iterative fashion for each sample of dataset. As the ripple signal is periodical, the **same measurements can be fed repetitively to the algorithm** while capacitance estimate continuously updates, resulting in **more stable and accurate results**.

Method **requires appropriate measurement covariance value tuning** for given amounts of samples and repetitions.

The other approach to DC-link capacitance estimation is usage of **neural networks**. Artificial intelligence solutions have to be trained on rather varied and large data base. As the obtaining measurements from the same DC-link at different capacitance values requires an considerable amount of resources, the idea to use **transfer learning** has emerged [2]. That approach utilizes mathematical model (**in-detail converter model needed**) for feature detector and classifier training to obtain amount of data required. Afterwards, only classifier undergoes additional training on **smaller amount of experimental records** – resulting in **easier process of implementation than classical deep learning**.



[1] Oliszewski, S., Pawlak M., and Dybkowski M. (2025) DC-link Capacitors Online Condition Monitoring Using Repetitive RLS in Hybrid-electric Aircraft. IEEE Access, 13, 131166-131176.

[2] Skowron, M., Oliszewski, S., Dybkowski, M., Jarosz, J. J., Pawlak, M., Weisse, S., Valire, J., Wyłomańska, A., Zimroz, R., & Szabat, K. (2024). Applications of the TL-Based Fault Diagnostic System for the Capacitor in Hybrid Aircraft. Electronics, 13(9), 1638.

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