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Direct Model Predictive Control of a Five-Level ANPC Inverter with an Adaptive Linear Neuron-based Impedance Estimator

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Abstract

The paper proposes a direct model predictive control (MPC) method for a five-level active neutral point clamped (5L-ANPC) inverter which includes an online impedance identification through an adaptive linear neuron (ADALINE) estimator. This is adopted to improve the robustness of the underlying MPC against load parameters uncertainty and wear-out, i.e., minimizing model mismatches, while keeping the computational complexity at bay. To this aim, the formulation of a single-layer neural network and the related online training for the application at hand is derived. The MPC optimization problem is designed such that the current reference tracking and the balancing of either the flying capacitors voltages and the neutral point voltage are addressed altogether. The presented results verify the effectiveness of the proposed strategy and demonstrate the performance benefits against impedance variations.

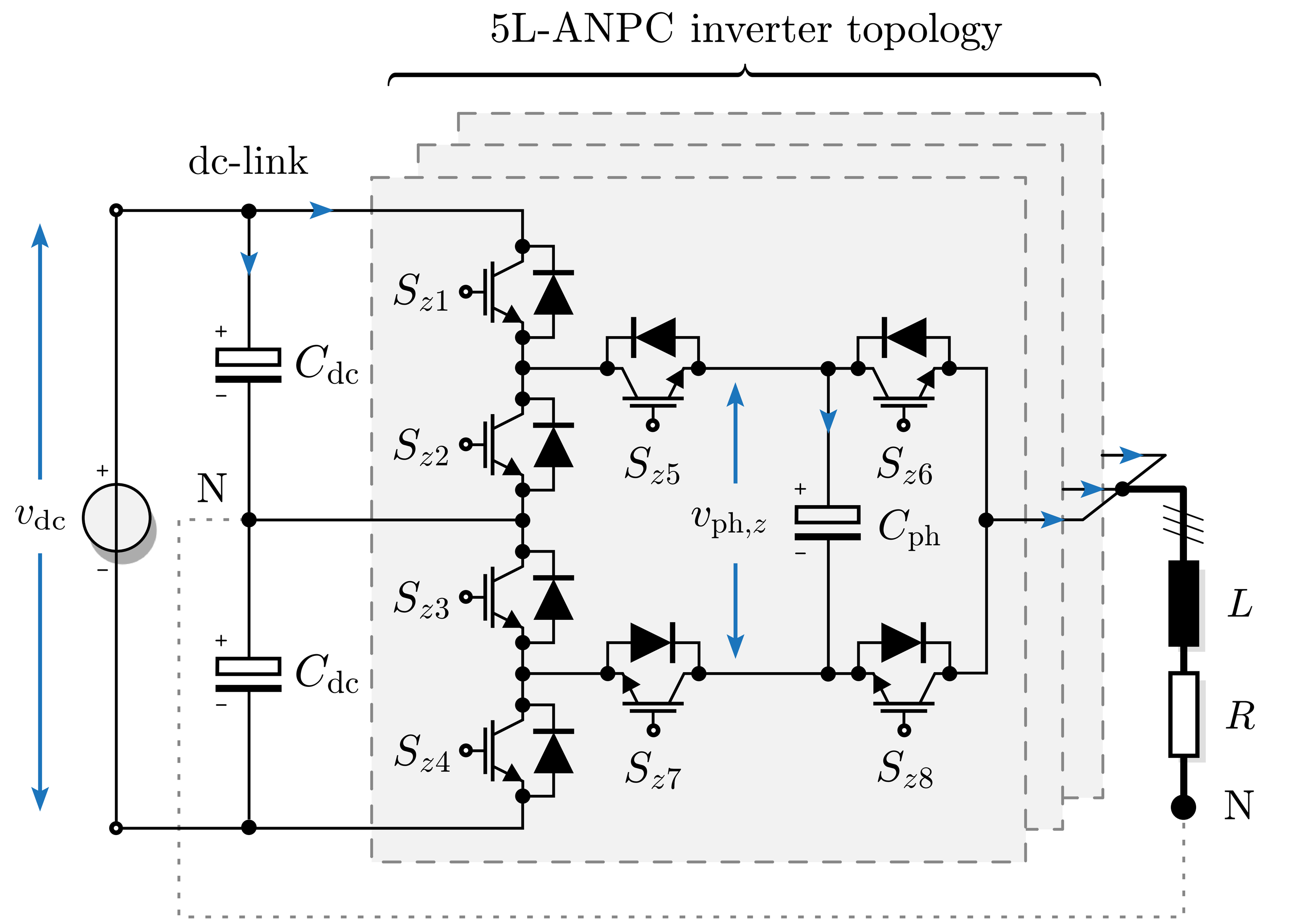

Fig. 1: Simplified circuit of a 5L-ANPC inverter (with focus on phase leg z) driving an RL load

Five-Level ANPC Inverter

The topology of a five-level ANPC inverter consists of eight switches and a flying capacitor *Cph* for each phase. The input DC source is connected to two DC-link capacitors *Cdc*. In a three-phase configuration, there are 512 (8^3) available switching state combinations and 125 (5^3) phase level voltage vectors.

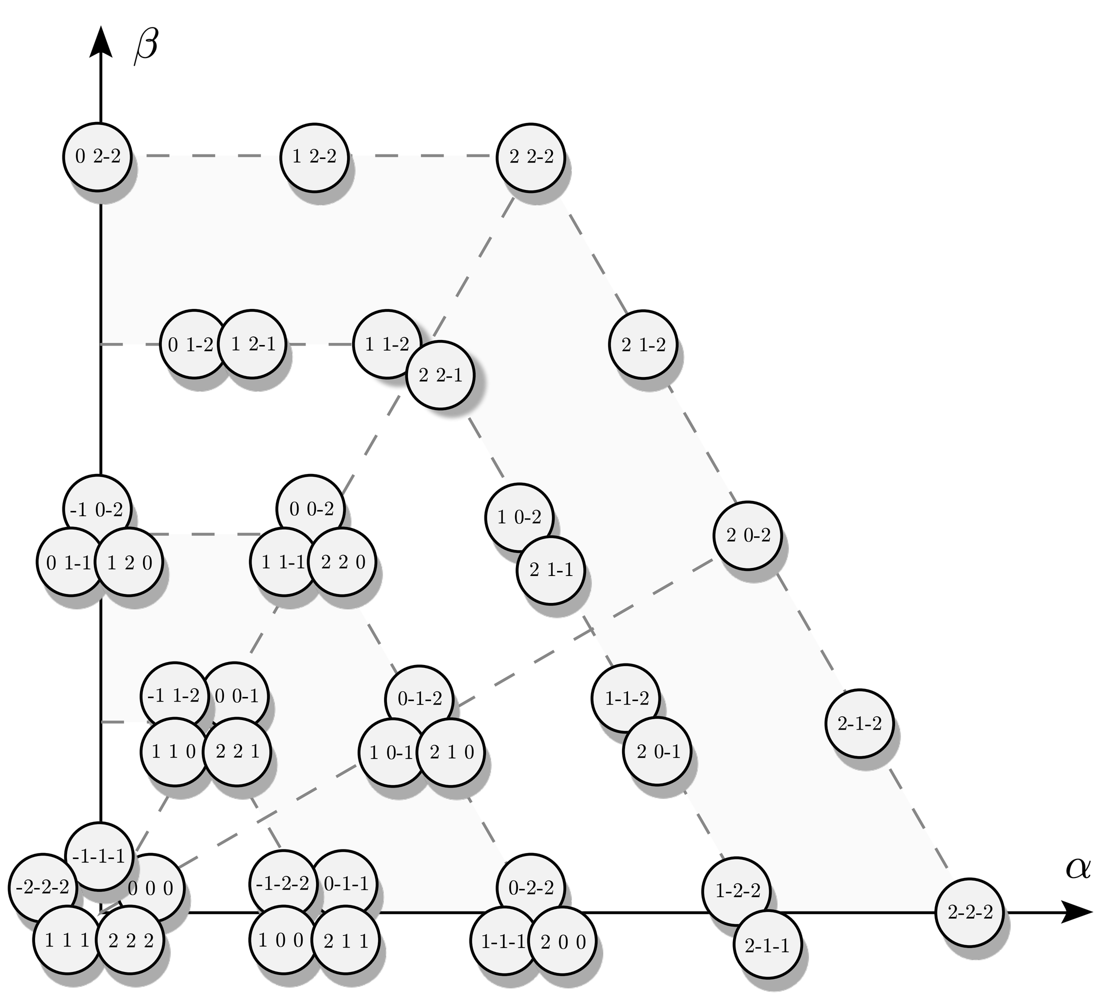

Fig. 2: Voltage vectors produced by a 5L-ANPC topology in the $\alpha\beta$-plane along with the phase levels U_{abc} (only the first quadrant is shown)

Direct MPC with ADALINE-based Impedance Estimator

An adaptive linear neuron (ADALINE) estimator is used to handle parameter mismatches in the RL load by updating its weights until they match the desired parameters. The ADALINE estimator continuously monitors the system and makes real-time adjustments with simple calculations to ensure the accuracy of the model predictive control. This approach allows the system to adapt to changing conditions and maintain optimal performance.

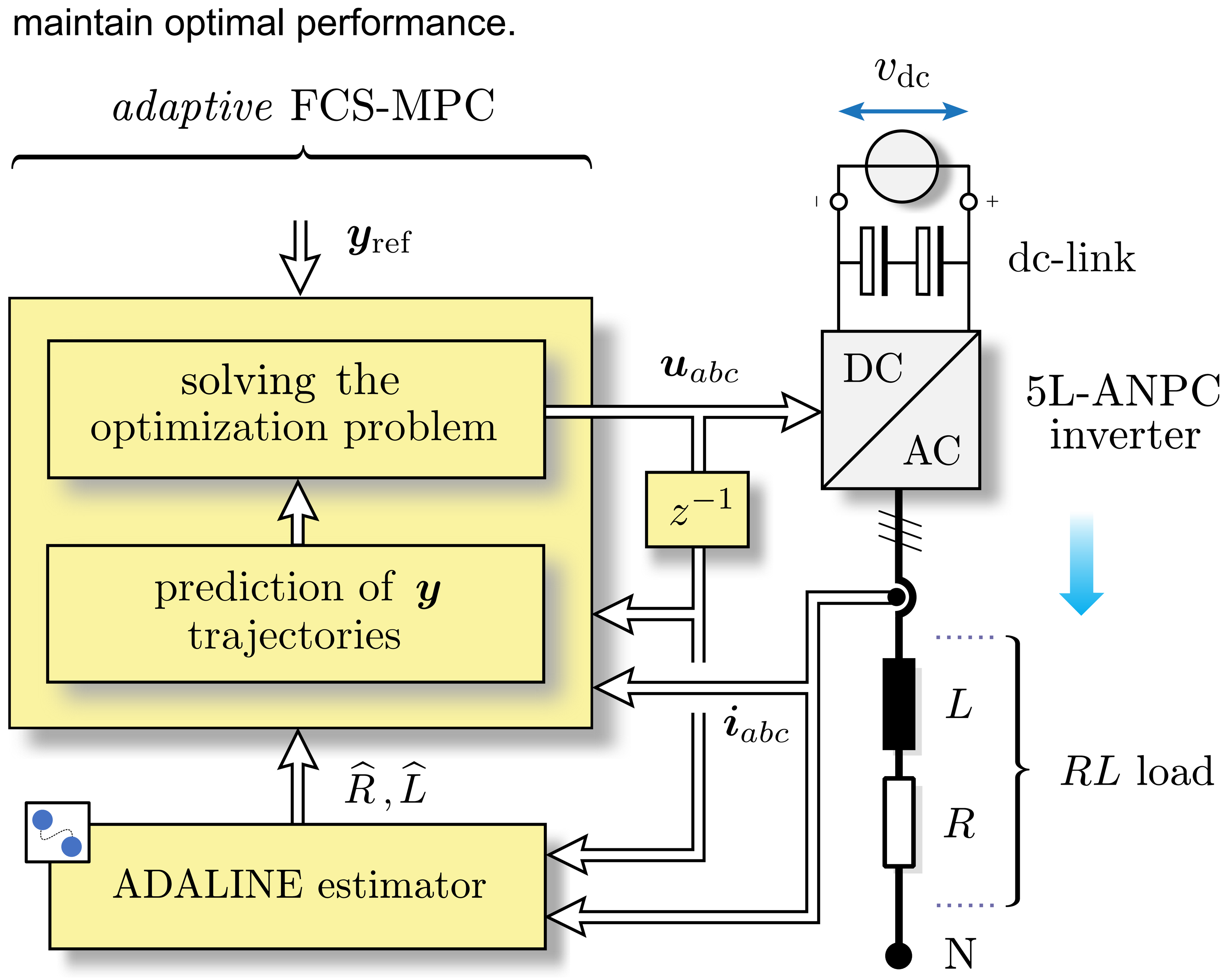

Fig. 3: Block scheme of the proposed direct MPC with the ADALINE estimator for the line/load impedance

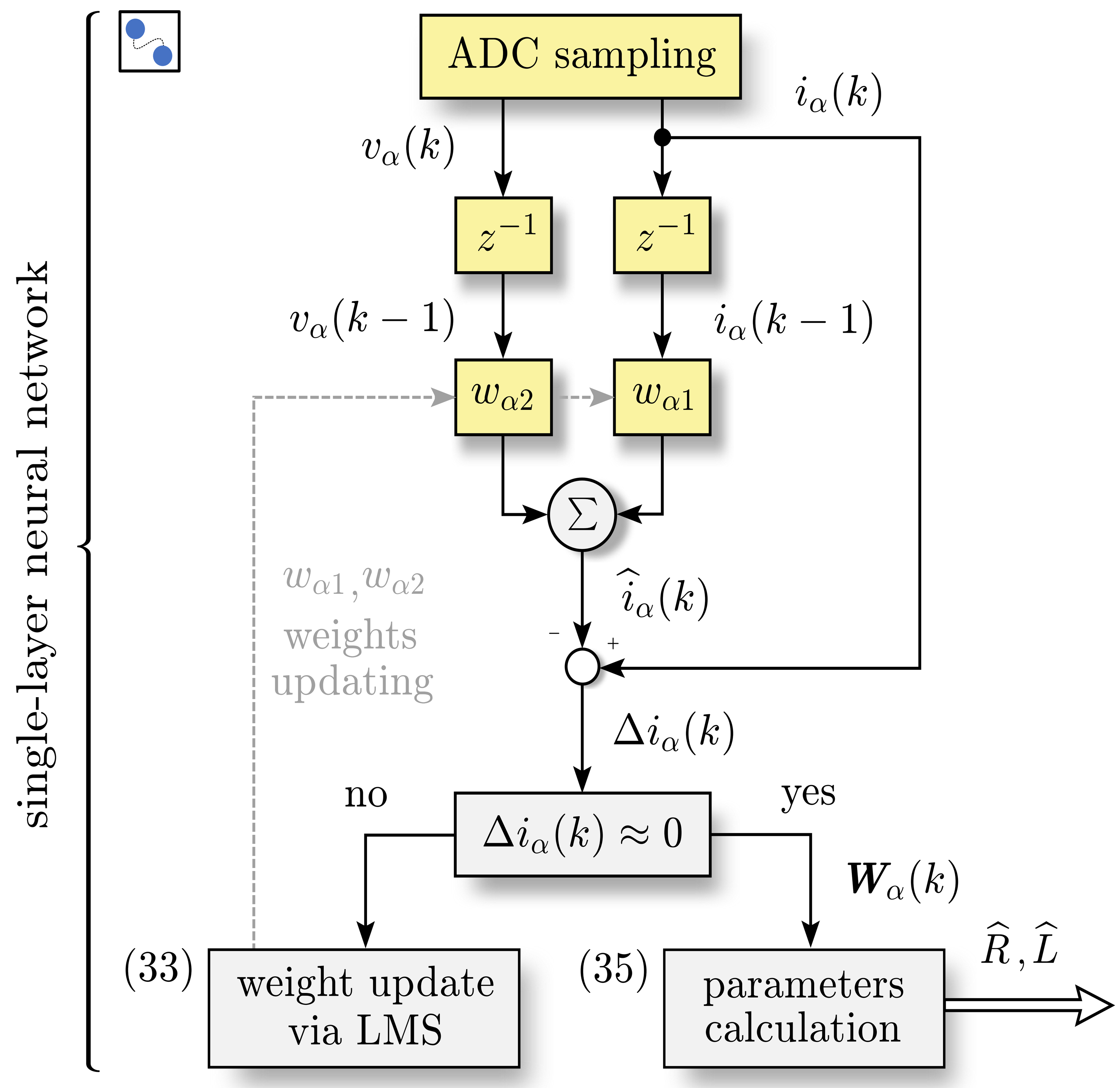

Fig. 4: Graphical representation of the ADALINE-based estimation principle for the α-component (hybrid flowchart)

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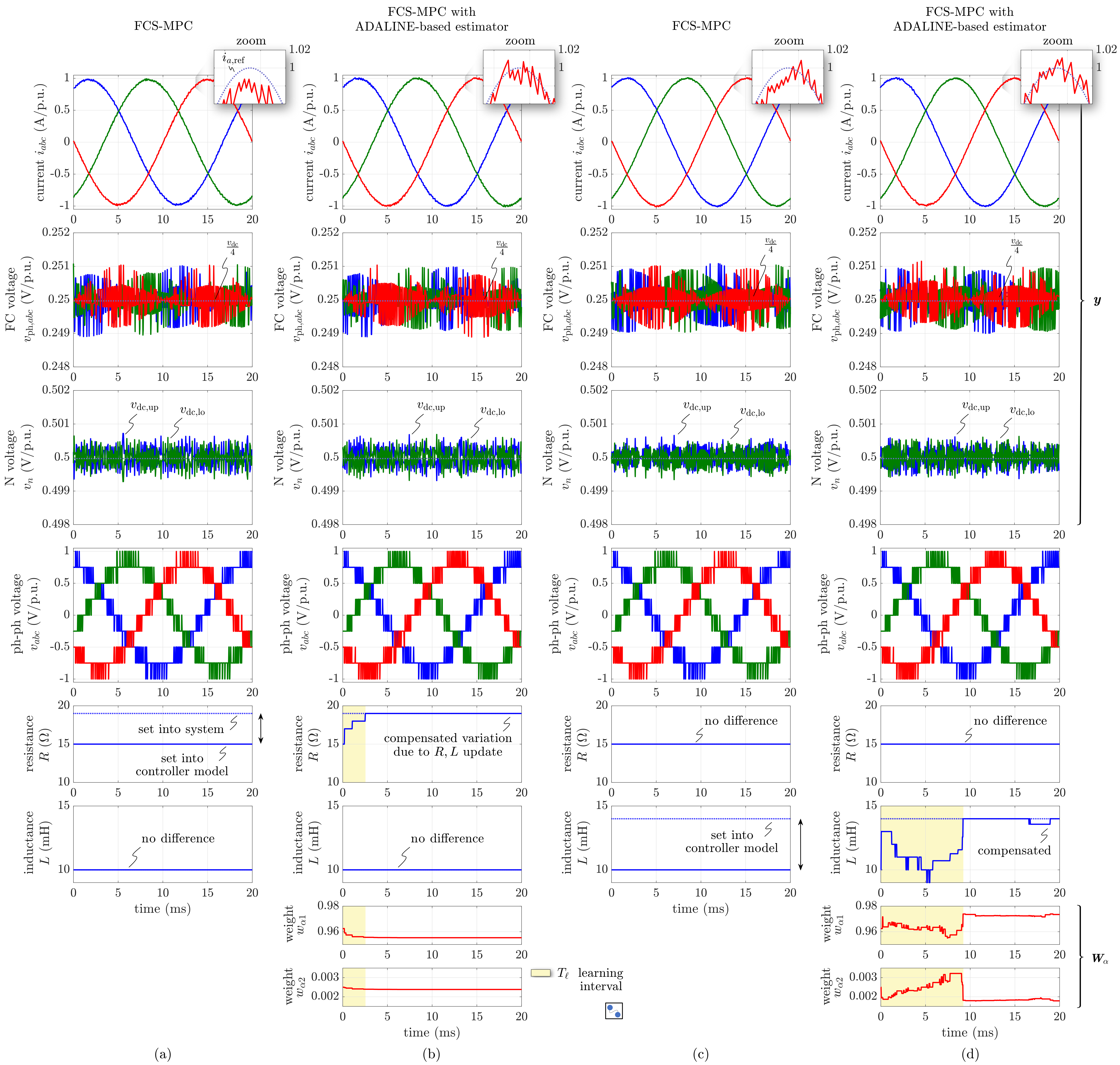

Fig. 5: Steady-state simulated waveforms in p.u. during (a) line resistance variation and (c) line inductance mismatches for a conventional FCS-MPC. The same parameter variations hold in (b) and (d), respectively, for the proposed FCS-MPC with an ADALINE-based estimator. The set $\eta = 0.0001$, $\omega_{\alpha 1}(0) = 0.97$ and $\omega_{\alpha 2}(0) = 0.0025$ is chosen and applied in both test cases, with $T_\ell \ll T_1 = 20$ ms, while λ_u is adjusted to achieve the same $f_{sw} \approx$ 4kHz.