Defining the System: The 9 State Variables

Identifying Energy Storage Elements

What Are State Variables?

Definition: State variables are the **minimum set of variables** needed to completely describe the dynamic behavior of a system at any instant in time.

For electrical circuits: We choose inductor currents and capacitor voltages because:

- Inductor current cannot change instantaneously ($L \cdot di/dt = v$ requires finite voltage)
- Capacitor voltage cannot change instantaneously ($C \cdot dv/dt = i$ requires finite current)
- These quantities store energy: $E_L = \frac{1}{2}Li^2$ and $E_C = \frac{1}{2}Cv^2$

Our 9 State Variables (Positive Half-Cycle Analysis)

iL1
Phase 2 input inductor current (positive cycle)

iL2
Phase 1 input inductor current (positive cycle)

iL3
Phase 1 input inductor current (negative cycle, inactive in this analysis)

iL4
Phase 2 input inductor current (negative cycle, inactive in this analysis)

iL5
Phase 1 output inductor current (delivers to C0 via D8)

iL6
Phase 2 output inductor current (delivers to C0 via D7)

vC1
Phase 1 coupling capacitor voltage (links L2 and L5)

vC3
Phase 2 coupling capacitor voltage (links L1 and L6)

vC0
Output capacitor voltage (DC bus voltage, feeds CPL load)

The State Vector

We assemble these 9 variables into a column vector **x(t)**:

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x(t) =
[ iL1(t) ] Phase 2 input (positive)
[ iL2(t) ] Phase 1 input (positive)
[ iL3(t) ] Phase 1 input (negative) - inactive
[ iL4(t) ] Phase 2 input (negative) - inactive
[ iL5(t) ] Phase 1 output
[ iL6(t) ] Phase 2 output
[ vC1(t) ] Phase 1 coupling capacitor
[ vC3(t) ] Phase 2 coupling capacitor
[ vC0(t) ] Output capacitor (DC bus)
```

Why 9 states and not fewer? Each energy storage element contributes one state. We cannot reduce this further without losing information about the system's dynamic behavior. The complexity comes from the interleaved dual-phase topology and bridgeless operation, which requires separate inductors for positive/negative AC half-cycles.