Critical Insight 3: Capacitor Functions in Energy Transfer

Coupling Capacitors (C1, C3)

Function:

Energy staging between input and output inductors

Charging:

Receive energy from input inductors (L1, L2)

Discharging:

Supply energy to output inductors (L5, L6)

Topology 11:

Net charging (iL2 + iL5), where iL5 < 0

```
dvC1/dt = (iL2 + iL5) / C1
```

Topology 00:

Net discharging (iL2 - iL5), where iL5 > 0

```
dvC1/dt = (iL2 - iL5) / C1
```

Pattern:

$dvC/dt = (i_{in} \pm i_{out}) / C$, sign depends on current direction

Output Capacitor (C0)

Function:

DC bus voltage regulation and load supply

Topology 11:

Pure discharge to CPL

```
dvC0/dt = -P/(C0·vC0)
```

Topology 10/01:

Partial recharge from one phase

```
dvC0/dt = (iL1+iL6-P/vC0)/C0
```

Topology 00:

Maximum recharge from both phases

```
dvC0/dt = (iL1+iL2+iL5+iL6-P/vC0)/C0
```

Complexity:

Number of terms increases with active delivery paths

CPL (Constant Power Load) Effect

Model:

P / vC0 = constant (tight voltage regulation)

Current:

i_{load} = P / vC0 (nonlinear relationship)

Stability Challenge:

Negative incremental resistance destabilizes system

Incremental Resistance:

$r_{inc} = dv/di = -vC0^2/P < 0$

Appears in:

Every dvC0/dt equation as -P/(C0·vC0) term

Control Impact:

Requires careful compensator design for stability

Energy Flow Summary: C1, C3 act as energy staging buffers between input and output stages. C0 regulates DC bus voltage against CPL load. The CPL's negative incremental resistance effect must be addressed in control design through appropriate damping and compensation to ensure stable operation across all operating conditions.