Announcements

• Experiment 1 Reports
  – Give all parameters needed to repeat
  – Reference specific features in figures/tables from text

• Experiment 2 Report due Friday
  – Demo full power in lab Wednesday

• Exp.3 prelab moved to Wednesday 2/12
Controller Implementation

Advantages of AMC:
- Direct control of current
- Simplifies compensation design
- Allows simple high gain voltage control

BW of current loop is at least an order of magnitude above CBU voltage loop.

Average Current Mode Control (ACMC) vs. CPM

- Current Programmed Control (CPM) from Chapter 12 is not ACMC
- Both possess many of the same benefits, but ACMC has:
  - Simpler compensation
  - Better noise immunity and accuracy
Nonlinear, Averaged Circuit

\[ L \frac{d\langle i_L \rangle}{dt} = \langle v_{\text{bus}} \rangle - (1 - d)\langle v_{\text{bus}} \rangle \]
\[ C \frac{d\langle v_{\text{bus}} \rangle}{dt} = (1 - d)\langle i_L \rangle - \langle i_{\text{bus}} \rangle \]

Suitable for simulation

Nonlinear, Large-Signal Equations

\[ \langle v_\phi \rangle = L \frac{d\langle i_L \rangle}{dt} = d(t)\langle v_g(t) \rangle + d(t)\langle v_{\text{bus}} \rangle - \langle v_{\text{bus}} \rangle \]
\[ \langle i_{\phi} \rangle = C \frac{d\langle v_{\text{bus}} \rangle}{dt} = -\frac{\langle v_\phi \rangle}{R} + d(t)\langle i_L(t) \rangle - \langle v_{\text{bus}} \rangle \]

DC only

\[ \phi = v_g - D'v \]
\[ \phi = D'S_L - \frac{v}{R} \]
Small-Signal AC Averaged Equic. Circuit Model

Open-Loop Control-to-Current TF

Find

\[ G_{cd}(s) = \frac{\hat{I}_L}{\hat{d}} \bigg|_{\hat{v}_{\text{in}} = 0, \hat{i}_{\text{in}} = 0} \]

\[ \hat{v}_c = \frac{1}{\hat{s}C} \hat{v}_c = \frac{1}{\hat{s}C} \left( \frac{\hat{v}_{\text{in}} \cdot D}{\hat{s}C} + \frac{\hat{d}}{\hat{s}C} - \frac{\hat{v}_{\text{out}}}{\hat{s}C} \right) \]

\[ \hat{v}_{\text{in}} = \frac{\hat{v}_{\text{in}} \cdot D}{\hat{s}C} + \frac{\hat{d}}{\hat{s}C} \]

\[ G_{cd}(s) = \left( \frac{\hat{v}_{\text{in}} \cdot D}{\hat{s}C} + \frac{\hat{d}}{\hat{s}C} \right) \left( \frac{\hat{v}_{\text{out}}}{\hat{s}C} + \frac{\hat{d}}{\hat{s}C} \right) = \left( \frac{1 + \frac{C}{D} \frac{s}{\hat{v}_{\text{in}} \cdot D}}{\hat{s}C + \frac{D}{\hat{d}}} \right) \]
Open-Loop Control-to-Current TF

\[ G_{id} = \frac{i_{L}}{d} \left( 1 + \frac{s}{\omega_{cl}} \right) \left( 1 + \frac{s^2}{\omega_o^2} \right) \]

DC solution:
\[ D'I_L = I_{bus} \]
\[ \omega_{ri} = \frac{I_{bus}}{CV_{bus}} \]

Open-Loop Control-to-Current TF

\[ G_{ido} = \frac{I_{L}}{D'} = \frac{I_{bus}}{(D')^2} \]

\[ f_{z1} = \frac{1}{2\pi} \frac{I_{bus}}{CV_{bus}} \]

\[ f_{o} = \frac{1}{2\pi} \frac{D'}{\sqrt{LC}} \]
Current Control Loop

Current Loop Gain

\[
T(s) = G(s) \frac{1}{V_m} G(s) R_s
\]

\[
\hat{e} = R_s \hat{r}_d e - R_s \hat{r}_d - R_s \hat{e} - R_s G(s) \frac{1}{V_m} G(s) \hat{e}
\]

\[
\hat{E} = \frac{R_s \hat{r}_d e}{1 + T(s) V_m}
\]

Design goal #1: Extend range of \(T(s)\) over wide range of \(V_m\).

\[
\frac{T(s)}{\hat{E}} \rightarrow \infty \text{ as } T(s) \rightarrow 0
\]
Loop Gain & Stability

Design #3
System well stabilized
\( \Rightarrow \) Large \( P_m \)

Phase Margin Test

System stable \( \Rightarrow \)

\[ \phi_m = 180^\circ + \angle T(j\omega_c) \geq 0^\circ \]

\[ (\omega_c = ||T(j\omega)|| > 1 = \text{Gain}) \]
Closed-Loop Response