ECE 398GG – ELECTRICAL VEHICLES

12b. EV Charger Design

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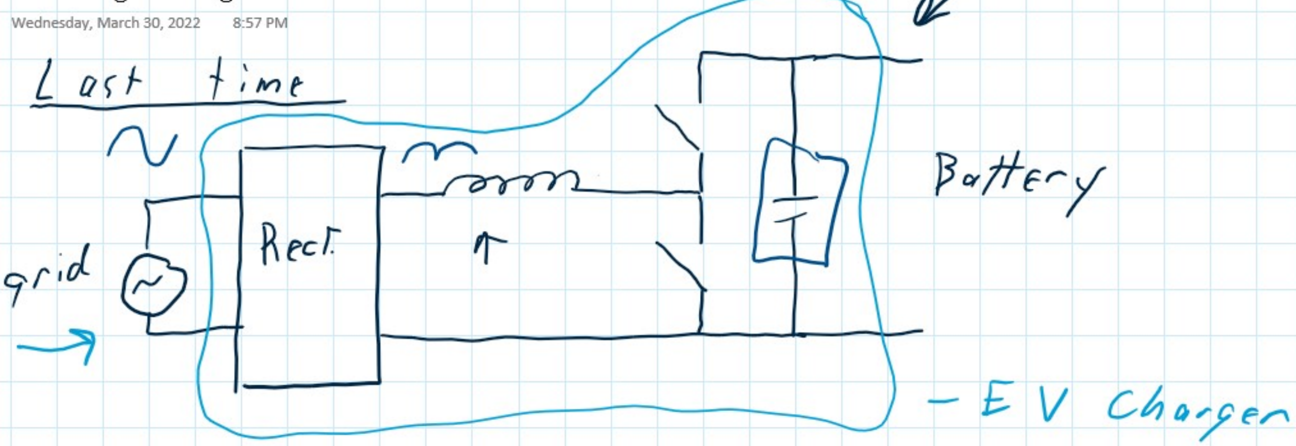
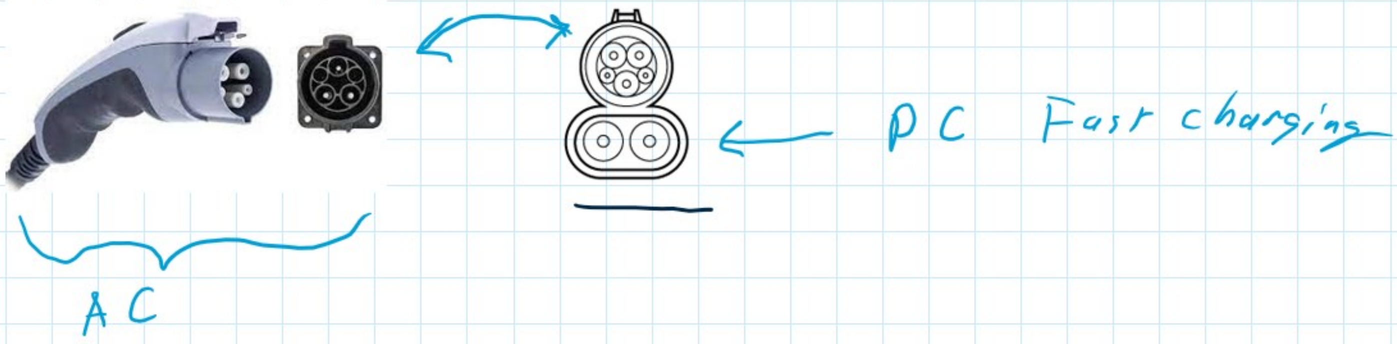
EV Charger Design Considerations

Wednesday, March 30, 2022 8:57 PM

Last time





- ↳ All EV chargers Follow Architecture
  - ↳ Variance, in topology, Filters, Voltage Levels

AC Chargers (U.S.)

Level 1: 120 VAC, ~ 1.4 kW ~ 12A

Level 2: 240VAC 4-17 kW, 30A-80A

↳ up to 20-25 miles / hour charge

AC Charger challenges

- ↳ Power is limited by current
- ↳ Charging is limited by on board charger

Energy Buffer

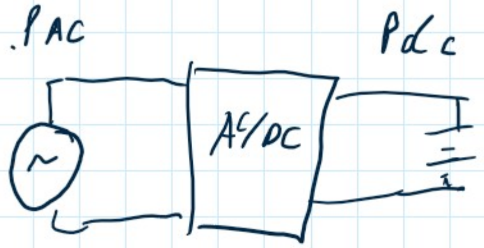
Recall: Instantaneous Power:

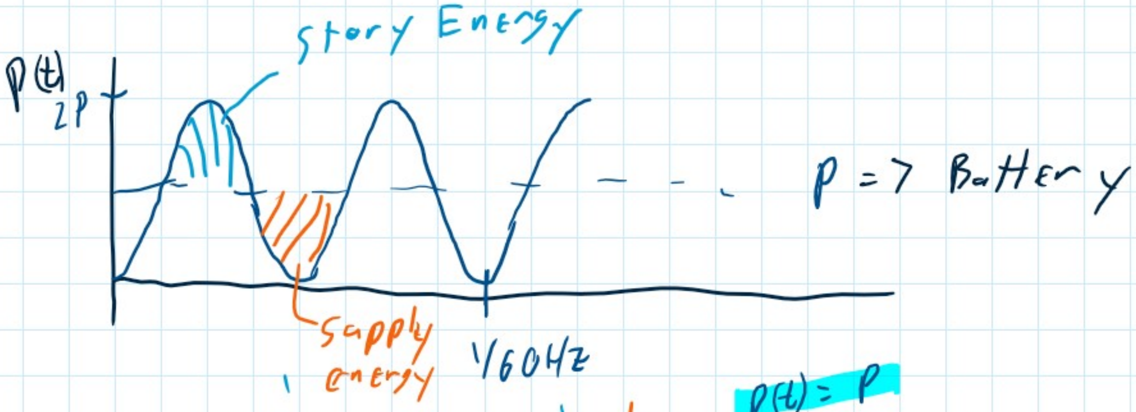
$$P(t) = \underset{V_{Rms}}{V}\cdot \underset{I_{Rms}}{I}\cos(\phi) + V\cdot I\cdot \cos(2\omega t - \phi)$$

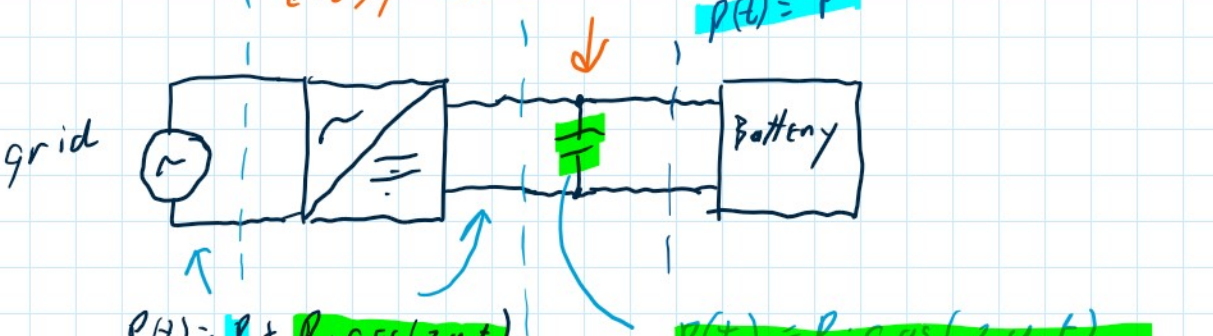
↳ at unity PF = 1

$$P(t) = V\cdot I + V\cdot I\cdot\cos(2\omega t) \leftarrow$$

$$\underline{\langle P(t)\rangle} = P = V\cdot I = \underline{P_{dc}}$$







$P(t) = P + P\cdot\cos(2\omega t)$

$p(t) = P\cdot\cos(2\omega t)$

↳ must include an energy storage buffer to store/supply difference in AC r DC Power

↳ Simplest is capacitor
  ↳ other methods exist

How? - allow some ripple on capacitor to store/release energy

↳ $P_C(t) = V_C(t)\cdot i_c(t) = P\cdot\cos(2\omega t)$

↳ $P_c(t) = V_c(t) \cdot i_c(t) = P \cdot \cos(2\omega t)$

↑

$V_c = V_{dc} + \tilde{V}_c$

→ $i_c(t) \tilde{=} \frac{P}{V_{dc}} \cdot \cos(2\omega t)$ $\ast$

$i_c(t) = C \frac{d\tilde{V}_c}{dt}$ ↖

$\tilde{V}_c = V_r \cdot \sin(2\omega t)$

$i_c(t) = 2\omega \cdot C \cdot V_r \cdot \cancel{\cos(2\omega t)} = \frac{P}{V_{dc}} \cdot \cancel{\cos(2\omega t)}$

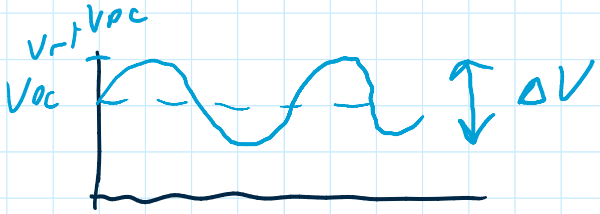
$C = \frac{P}{\underline{2}\omega \cdot V_{DC} \cdot \underline{V_r}}$

$\omega = 2\pi \cdot f$

↙

$$\boxed{C = \frac{P}{2\pi f \cdot V_{DC} \cdot \Delta V}}$$

↑ ↑



$\Delta V = 2 V_r$

↳ can only allow so much ripple (ΔV)
  ↳ not good for batteries

↳ as P goes up, must increase capacitance

  ↳ more volume / weight
    ↳ this is on board EV !

Examples - on board charging

Nissan Leaf - 6.6 kW
Kia Niro - 7.2 kW
Ford Lightning - 7.7 kW

How do we do "Better"? - DC Fast charging

Ford Lightning – [illegible] kW

How do we do "Better"? – DC Fast charging

↳ supply DC Power "Directly" to Battery

↳ Not a Residential charger

↳ charge with DC current
  ↳ still very high current, 100's A

↳ How do we get past Energy Buffer?

↳ Recall 3-ϕ Power

$$P(t) = 3 \cdot V \cdot I \cdot \cos\phi = \text{constant}$$

↳ 3ϕ constant = P_{dc} ⇒ ideally no need for energy buffer

↳ still need DC link capacitor for switching noise + transient response

↳ much smaller than buffering

<u>400 V vs 800 V</u>

↳ 400 V DC Fast charging most common

@ 800V, need half current to supply same power

@ 800V, need half current to supply same power

Porshe Taycan, Kia EV6 + variants

↳ use 800V charging

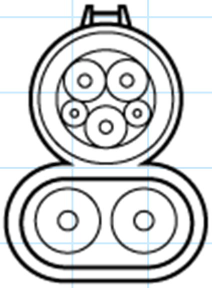
↳ Both can change @ 400V... at reduced power

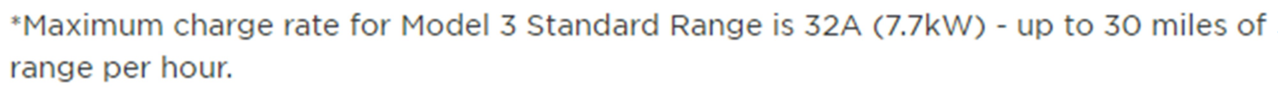
↳ unclear how this is implemented

Battery Charger

Monday, May 3, 2021 1:49 PM

- Residential (SAE J1772)
  - Level 1: 120 VAC, 1.4 kW, ~12 A
  - Level 2: 240 VAC, 7.2 – 19.2 kW, ~30-80 A
  - Up to 20-25 miles/ hour
- DC Fast Chargers (Level 3)
  - SAE Combo Combined Charging System (CCS) most common
  - Up to 400 kW
- Note: charging rate is limited by charger and by vehicle





*Maximum charge rate for Model 3 Standard Range is 32A (7.7kW) - up to 30 miles of range per hour.