Safely Charging EV and PHEV from the Electricity Grid

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Facts about Lithium Ion Batteries

• Lithium ion batteries do not like over charge or over discharge
  – Potential damage and hazards/risks

• Construction of lithium ion battery
  – Very thin metal (15 to 50 um),
    • Cu for anode, Al for cathode
  – Metal oxides, powder
  – Plastic material for packaging
  – Flammable acidic liquids

• Highly sensitive to defects, process impurity, improper packaging, and improper handling
Source of Hazard/Risks

• Oxygen
  – Released from layered cathode during over charge
  – Oxygen access to cells after rupture/opening via gas pressure buildup or external impact

• Combustibles
  – Lithium
  – Electrolyte (solvents and salts)
  – Gasses (hydrogen rich)

• Heat/Energy release via anode and cathode decomposition
  – Cell short, internal or external
Safety: A Major Concern

- Battery safety
- Electricity safety

Fire Damaged PHEV Prius

Before

After
Issues of Lithium Batteries

• Safety
  – Electrolyte spill
  – Smoke
  – Fire
  – Explosion

• Capacity fade
  – Less miles every month

• Life cycle
  – Battery end of life earlier than expected
  – Deep discharge, charge sustain, vs. battery life

The pain is exacerbated in large lithium ion battery systems
Batteries Fail due to Many Reasons

- Electrolyte spill due to over current.
- Cell voltage became negative.

- Unbalanced charge
- Over charge

- Over heating
- Over current
- Over discharge

Battery charging and management is one key aspect of battery/Ev safety.
What Can Electricity Do?

In the US, per year, due to electricity:
- 600 death
- 3600 disabling injury
- 4,000 non-disabling injuries
- 9% of all industrial fatalities

Electric Shock
Arcing
Blast

EV Needs to be charged from the utility grid

http://ehs.okstate.edu/modules/electric/index.htm
Risks of High Voltage Batteries

- **Electric**
  - Electric shock: manufacturing personnel, service personnel, emergency responders, owner

- **Thermal**
  - Smoke
  - Fire
  - Explosion

- **Chemical**
  - Acid spill
  - Toxic gas
  - Burns
Risks of High Voltage Batteries

• Low/short term risks
  – Injury: burns, electric shocks,
  – Market risks (bad image)

• Medium/middle term risks
  – Loss of property
  – Disability

• High/long term risks
  – Loss of life
  – Loss of business/income
  – Loss of opportunity
  – Dead of EV industry (another era of EV…)
Charging Technology

- Direct charging, or conductive charging
  - There is direct electrical contact between the batteries and the charger. Conductive charging is achieved by connecting a device to a power source with plug-in wires.

- Inductive charging
  - Energy is transferred through electromagnetic coupling, not direct wire connection – close proximity

- Wireless charging – through a distance
Advantages of Inductive Charging

- Low risk of electric shock
- All weather proof due to no exposed wire
  - Especially in public charging stations
  - Prevent water flow in so as to prevent short circuits due to water
Disadvantages of Inductive Charging

- Low efficiency
- Low power
- Manufacturing complexity
- High cost
- Equipment specific (no exchangeability)
- Charge station is needed
GM EV1 Magne Charger

- 208-240V/32A input
- 60Hz
- 6.6kW
- 25kg (55 lb)
- Efficiency 86% at peak power

Isolated Charger Topology

- Isolated architecture
- Phase shifted control

AC

Rectifier

PFC

DC-AC

AC-DC

Of Interest
There are three types of inductive couplers.
Wireless Charging

• Wireless changing is different from inductive charging, and information transmission, such as radio signal.
• Wireless means transferring power and energy in a great distance.
• It is typically done through electromagnetic resonance.
• MIT and University of Tokyo, some of the leaders in this area.
Wireless Charging
Wireless Charging of EV

Parked Car

Receiver

Source of power
Resonant Topology

Power is transmitted wirelessly in a distance. Frequency at 10MHz or more
Current Issues and Future of Wireless Charging

• Efficiency is low (20%??)
• Distance is not great (30 cm ??)
• Size is too big
  – For 100W, the size of the coils exceeded 50 cm for distance of 50 cm
• Potential use with ultra cap
• Electrified highway, etc.
A Compromise

- Home charging using conductive charging
- Public charging station using inductive charging
- ???
- This does not seem possible since these are two different technologies, unless each car is equipped with
  - Two different chargers!!!
Costs and forecast how the costs will decrease

- Cost and efficiency are two major factors
- Cost will only decrease as the quantity goes up
- Power semiconductor technology can play a role
- Silicon Carbide devices can further increase switching frequency hence reduce weight of coupling
Prototype PHEVs at UMD

• Three PHEV’s were converted
  – Prius PHEV (7kWh, equi. E-range 30 miles)
  – Chrysler Aspen (11kWh, equi. E-range 21 miles)
  – Chrysler Minivan (11kWh, equi. E-range 25 miles)
  – Saturn Vue (underway, 10kWh, equi. estimated E-range 30 miles)

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