ECE 421: Midterm Project

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THE ELECTRIC VEHICLE

Agenda

- History & basic theory of the technology
- State-of-the-art designs and products
- Impacts (technical and social)
- Challenges or R&D focus for the next 5-10 years
- True stories of its application or demonstration
- Related research papers published in the past 5 years

Lily Hoang

History & Basic Theory of the Technology

Over 100 Years of History

Electrobat cabs in front of the Old Metropolitan Opera House in New York in 1898.

1896

<u>The First Fleet Vehicles</u>

The Electric Vehicle Co. introduced electric cabs to New York City in 1896, and by 1899 the city had more than 60 of them. The cars were intended to fix the significant waste problem from horse-drawn carriages. Cab companies didn't believe there was a market for personal cars because it would require knowledge of electricity. Consumers did end up purchasing their own, however, because of how easy they were to use.

An early electric car travels down Hennepin Avenue in Minneapolis.

1900

<u>Electric Advantages In The Market</u>

In 1900, there were more than 4,000 cars on the road -- a third each electric, gasoline and steam-powered. The electric car was quicker to start up than the steam-powered vehicle, and cleaner than the internal combustion engine. Electric cars would also do well in the snow where others couldn't make it, but cold weather was a drain on battery life. Modeled after stylishly designed carriages, electric cars in this time period would last about 35 miles per charge.

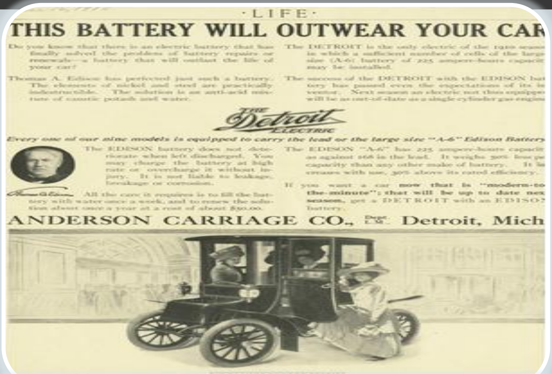
Henry Ford stands next to an electric car that Thomas Edison gave him for Christmas in 1913.

1908

<u>Rise Of Internal Combustion Engines</u>

Henry Ford introduced the Model T in 1908 for $850. By comparison, Anderson Electric, one of the most popular electric car manufacturers, sold its cars for around $2,000. The Model T's production method would eventually overtake electric vehicles. But even Ford's wife, Clara, bought an electric car for herself -- like many women of the time, she preferred its cleanliness and ease of use to gas-powered cars.

Over 100 Years of History



An advertisement from LIFE magazine shows off a new Thomas Edison battery in a Detroit Electric car.

1910

The Battery Question

From the start, marketers knew batteries were an issue for consumers. This ad from 1910 hails a battery, invented by Thomas Edison, that "will outlast the life of your car." Edison was a major force in the battery market, and his nickel-steel battery replaced the lead one, raising the average driving range from 65 to 100 miles. But range anxiety was an issue: One journal article from 1911 noted, "If charging stations could be readily found in every town where there is electric service, the use of electric pleasure cars on fairly long runs would become much more common than it is now."

A Detroit Electric car makes a stop at a charging station in Nisqually, Wash., on a publicity trip from Seattle to Mount Rainier.

1920

The Downfall Of The Electric Car

With more developed roads, car owners wanted to go farther than electric car charges allowed. Many rural farms stocked jugs of cheap gasoline from newly drilled oil fields in Texas, but few had electricity. And the invention of the electric starter meant people were less involved in operating the dirty and dangerous internal combustion engine. By the late 1920s, the electric car was nearly gone from the market.

An Environmental Protection Agency symposium in Ann Arbor, Mich.

1973

The Middle Years

The period from the mid-1920s to the early 1990s saw little large-scale production of electric cars. Most were concept cars or small test fleets, which surged in popularity depending on historical events. In England, for example, electric cars became popular as a delivery vehicle during both world wars to save gasoline. Fuel shortages and environmental concerns in the 1970s also had U.S. developers eyeing electric power. Most cars ended up like this Sundancer -- a futuristic prototype never produced on a large scale.

Over 100 Years of History

Dave Modisette charges his General Motors EV1 electric car in Sacramento, Calif.

1996

<u>Return Of The Electric Car</u>

In 1996, GM unveiled the EV1, an electric car that traveled about 80 miles per charge. The car was developed partially in response to the California Air Resource Board's 1990 ruling that 10 percent of the state's cars must produce zero emissions by 2003, which was later rolled back. EV1s were only available for lease and were taken out of commission in 2003, upsetting many owners. The car was the subject of the 2006 documentary Who Killed the Electric Car?

A Tesla Roadster at a flagship showroom in Los Angeles.

2006

<u>A Luxury Market</u>

In 2006, Tesla Motors (named after Nikola Tesla, an inventor who worked with Edison) unveiled the Tesla Roadster. Priced over $100,000, the car was meant for a high-income market and aimed to show off what an electric engine could accomplish. The company stopped taking orders for the car in 2011. A second-generation Tesla, with a starting driving range of 160 miles, will go on sale next year at around $58,000.

A Nissan Leaf charges at an electric vehicle charging station in Portland, Ore.

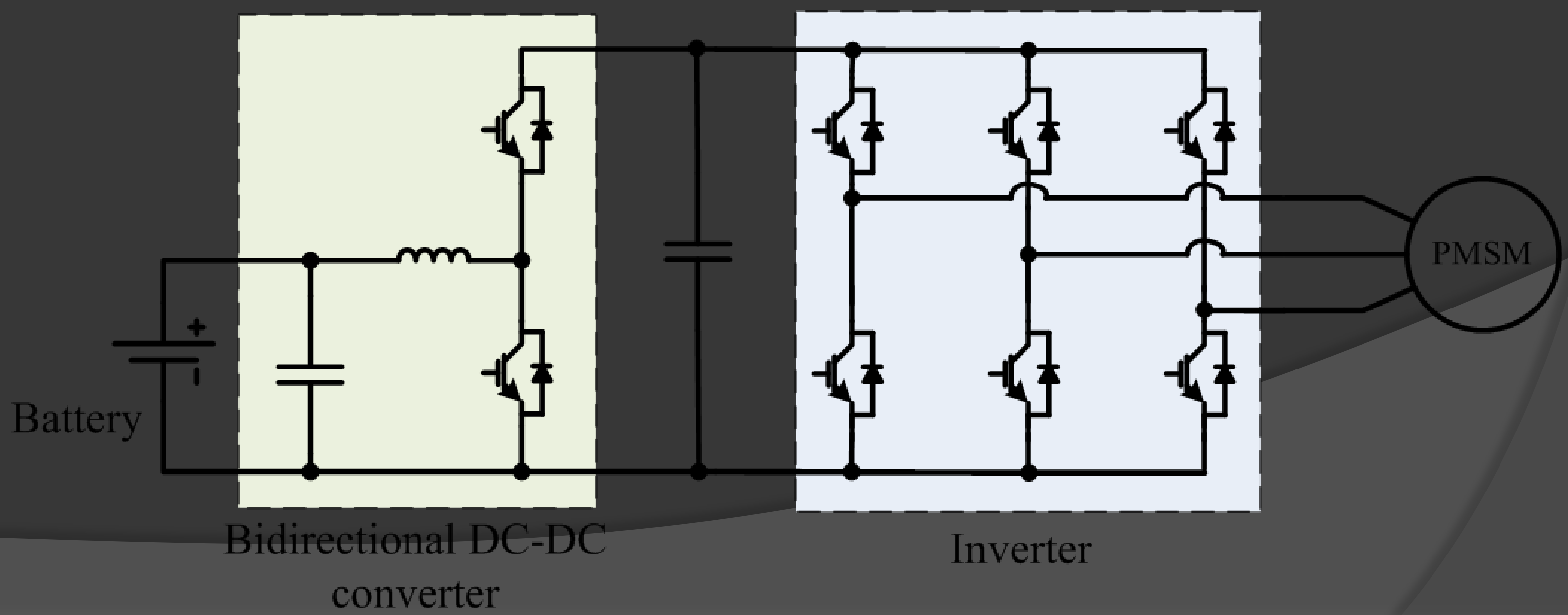
2010

<u>The New Electric Generation</u>

The all-electric Nissan Leaf went on the market in the fall of 2010. The Leaf can go up to 100 miles per charge and costs around $35,000. Nissan has sold more than 8,000 of the vehicles so far. Like other electric vehicles on the market (the Smart Fortwo, Chevy Volt and the coming electric Ford Focus), the Leaf faces similar problems to those that ailed electric cars at the turn of the last century: consumer desire for longer battery range and a less expensive product.

Basic Theory of the Technology

- DC electricity from the battery is fed into a DC-DC converter and then an AC inverter where it is converted to AC electricity
- This AC electricity is then connected to a 3-phase AC motor which runs the vehicle
- Hybrid: Bidirectional DC–DC converter is used to manage two-way energy transfer and cascading Hybrid Energy Storage System to DC-bus system

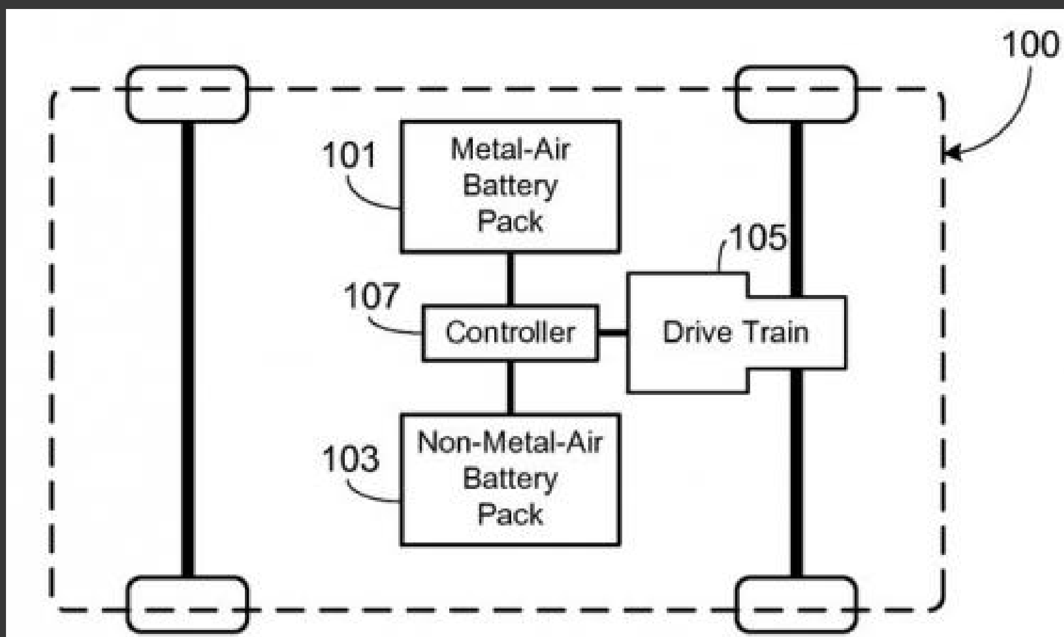


Jonathan Heacker

State-of-the-Art Designs and Products

Dual-Battery System

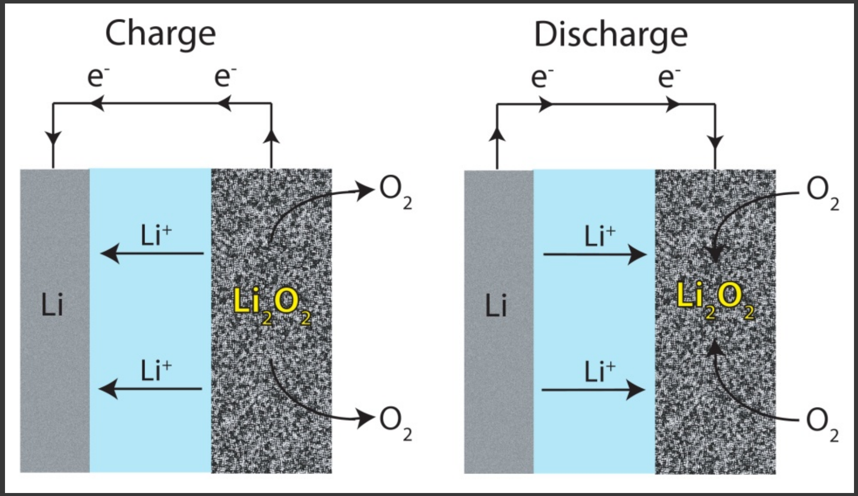
- Tesla Motors Patents Hybrid Battery System for electric vehicles.



TESLA MOTORS

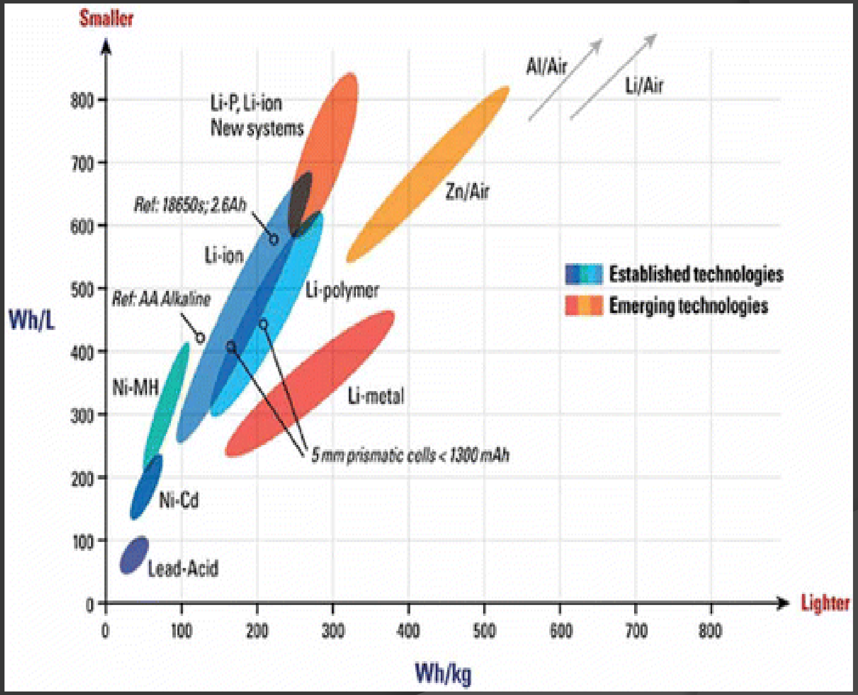
Metal Air-Batteries

- Lithium-Air Battery



$$4Li + O_2 \rightarrow 2Li_2O$$

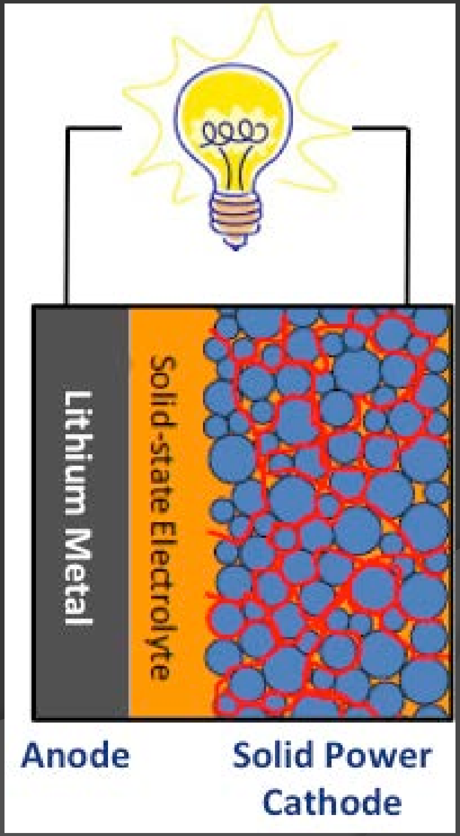
- Energy Density of Batteries



Solid-State Power

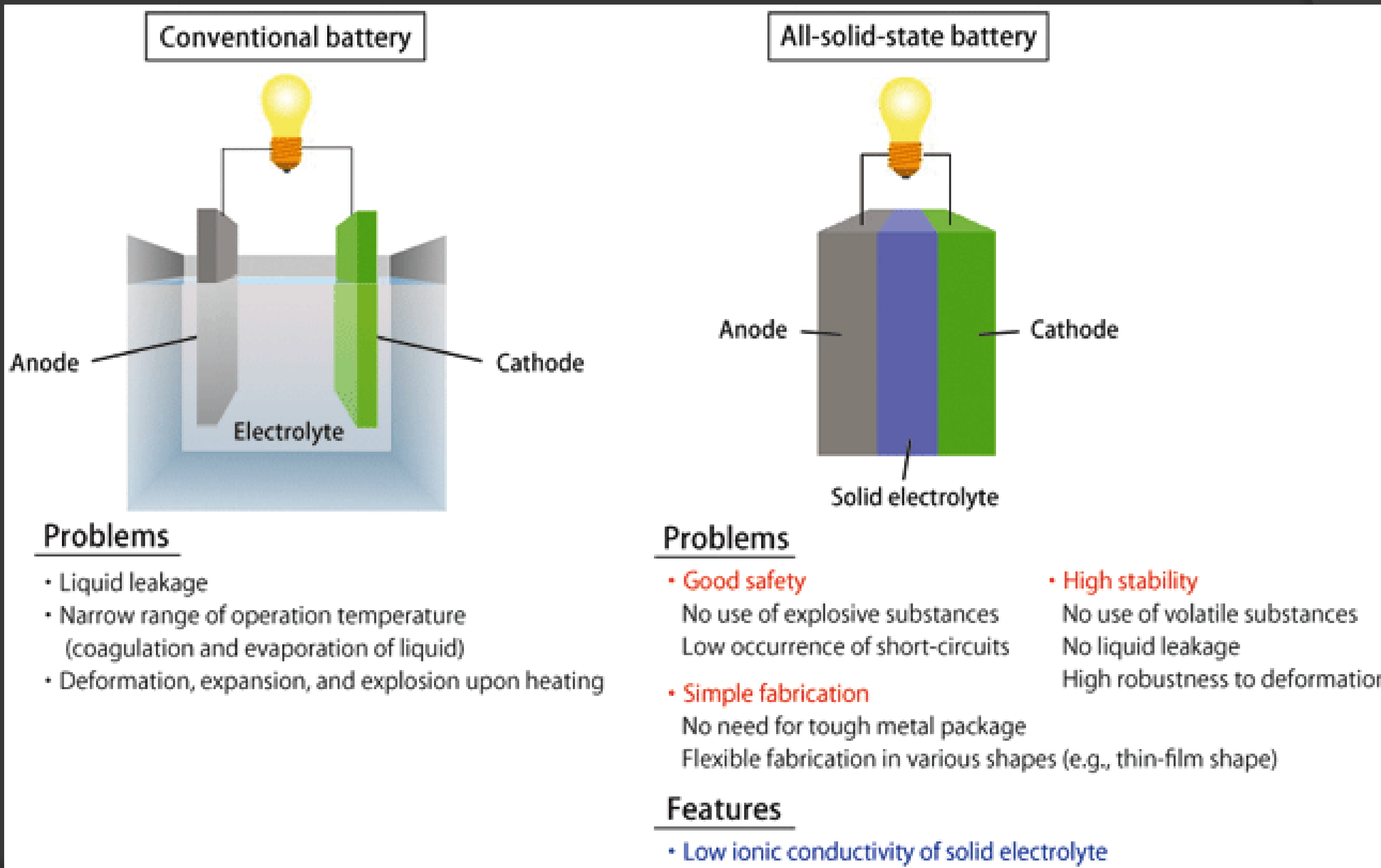
- Solid Power's solid-state battery

- View of Solid Power's Battery (Internally)



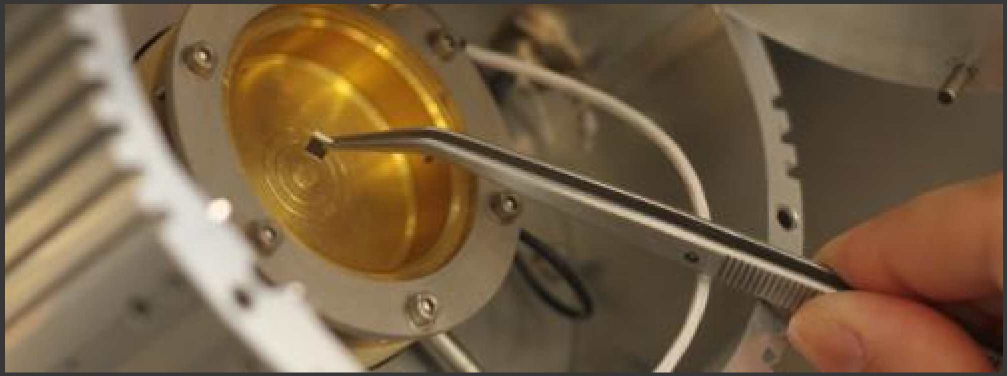
SolidPower Battery

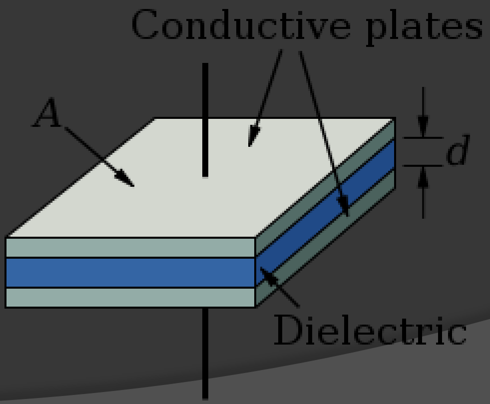
Solid-State Battery



State-of-the-Art Capacitor

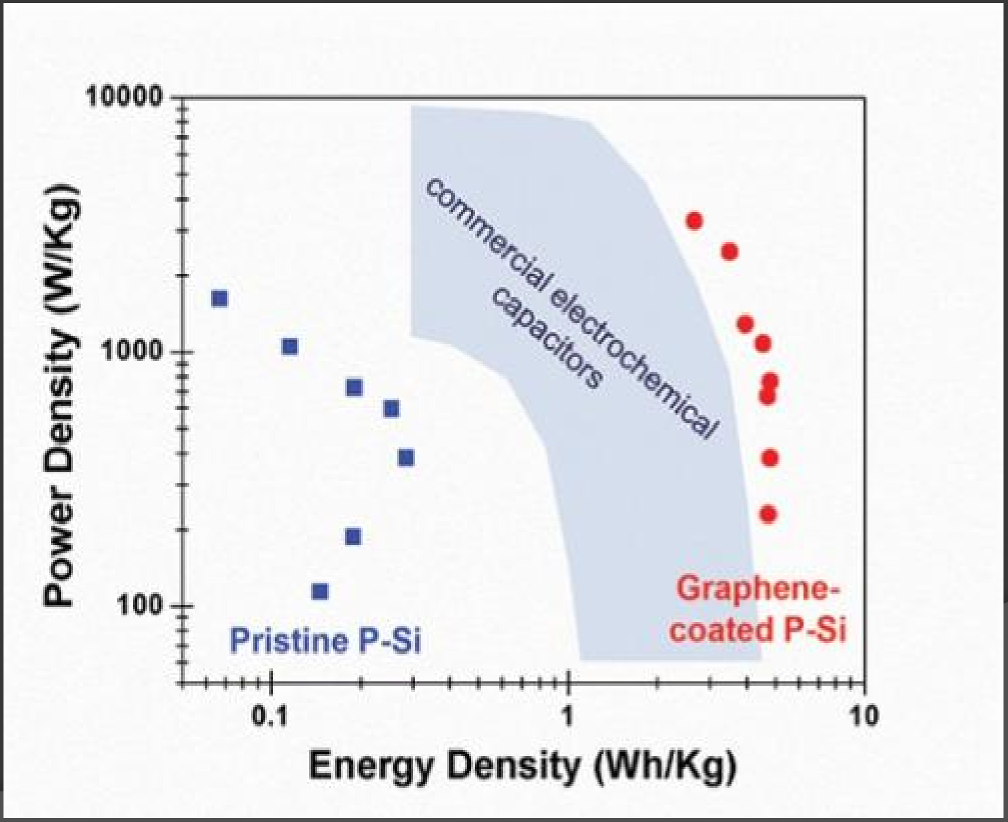
- New Capacitors that can improve the electric vehicle by increasing performance and reducing weight





State-of-the-Art Designs or Products

- Power Density (W/kg) and Energy Density (Wh/kg) of Porous Silicon, Graphene-coated Si, and carbon based capacitors



Christopher Newman

Impacts (Technical and Social)

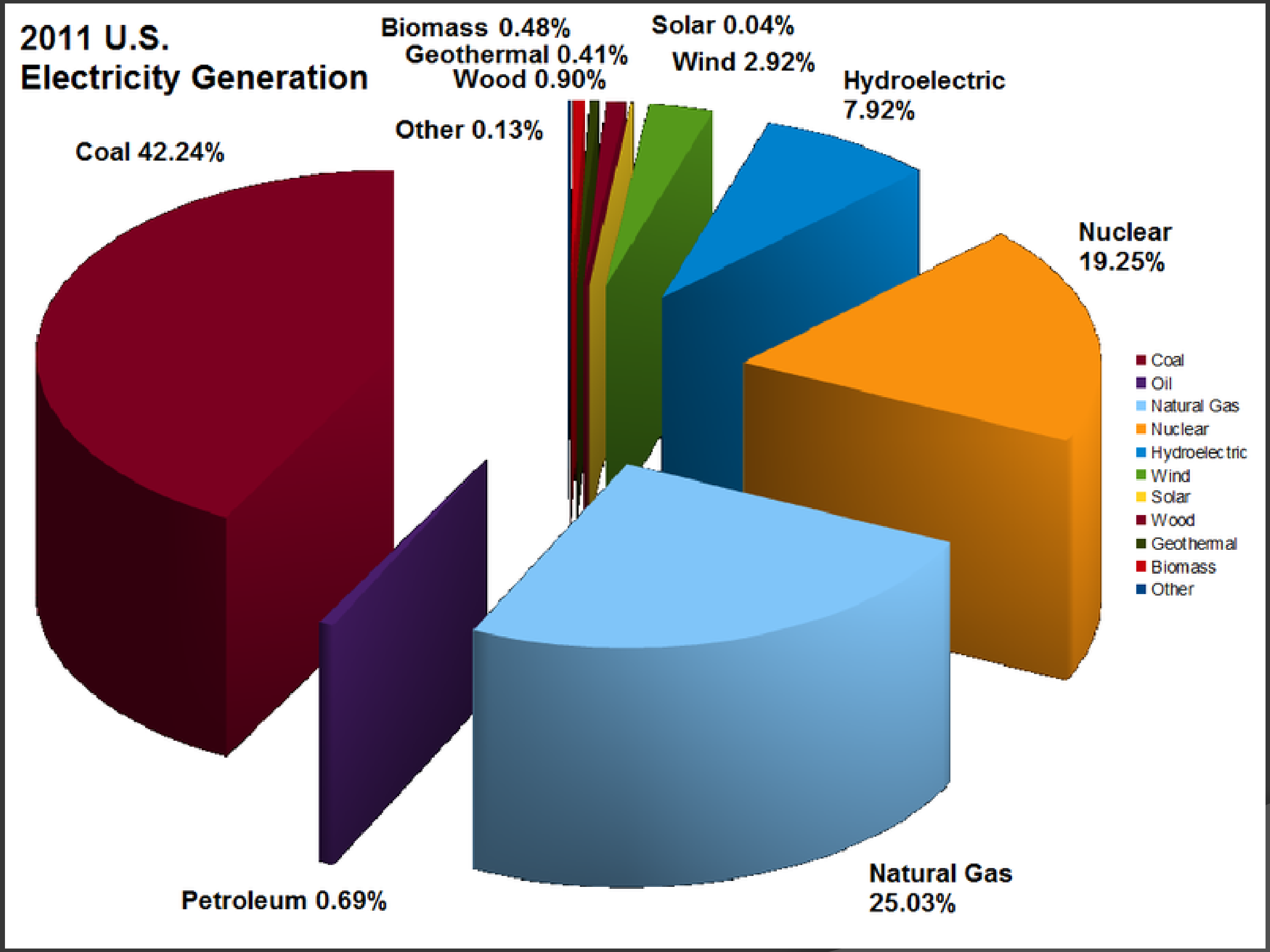
Impacts

- Environment benefit
- Grid
- Social – Daily life

Environmental Impacts

- No green house gas emissions from the car
  - Does not burn fossil fuels
- How much is it really helping?
  - Majority of energy still produced by fossil fuel burning plants
  - Transmission line losses

Energy Generation

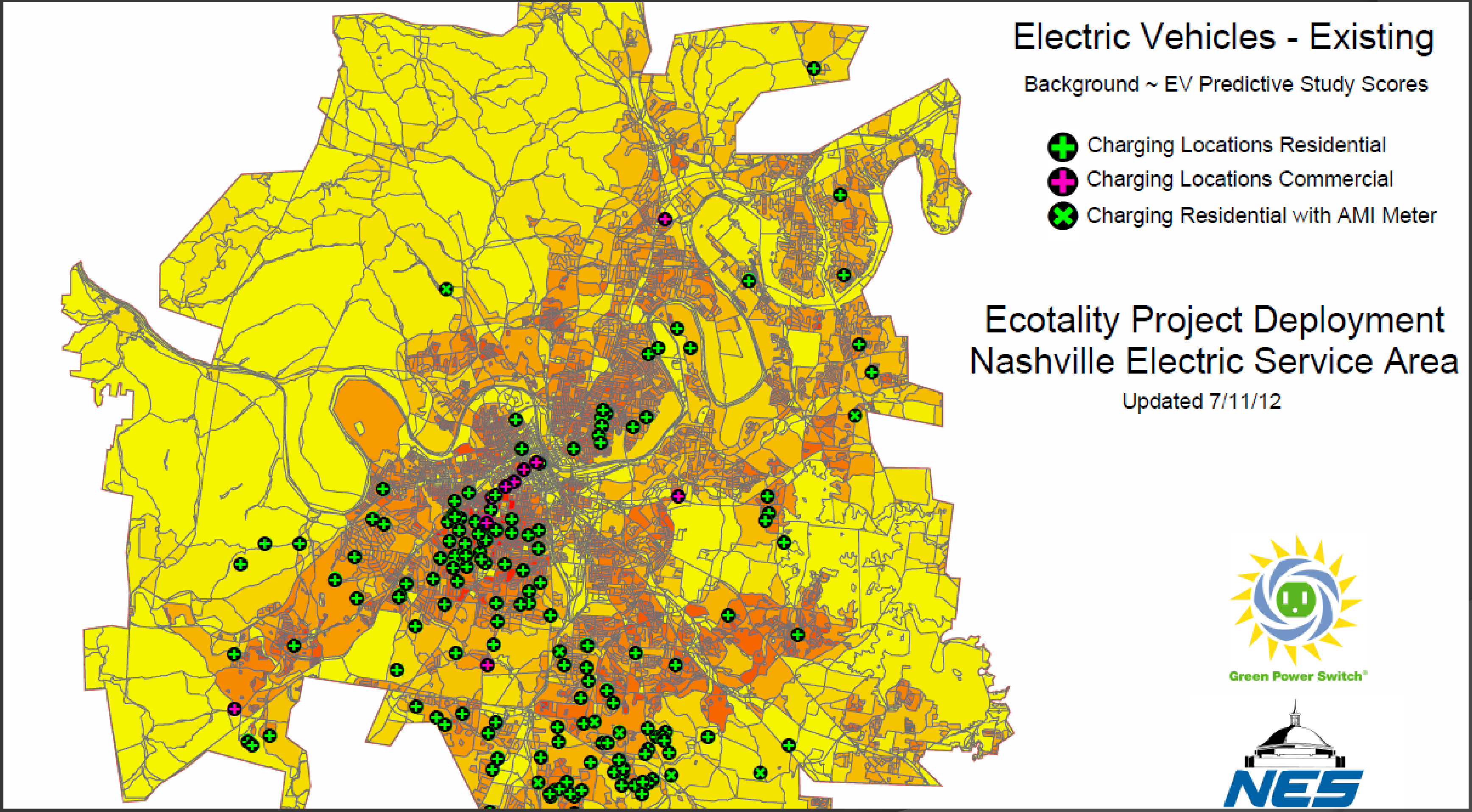


From wikipedia.org "Electricity sector of the United States"

Power Grid Impacts

- Energy for the car is now coming from the power grid
  - Charging Stations
- Will add a significant amount of load to the grid if the EV continues to evolve and catch on
  - Issues include Phase balancing and Transformer loading
    - “Clustering”

Nashville Area EV's



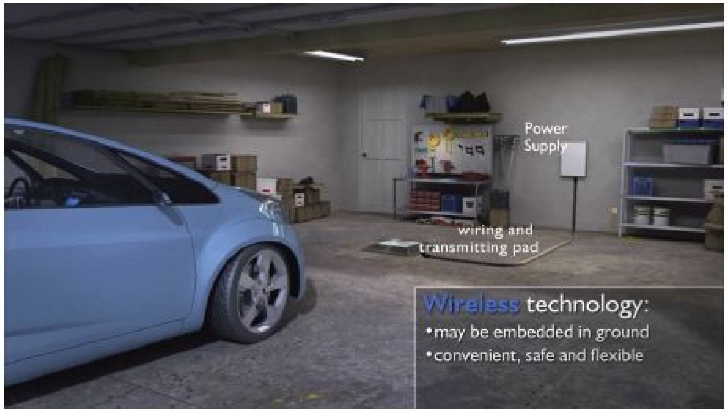
Social Impacts

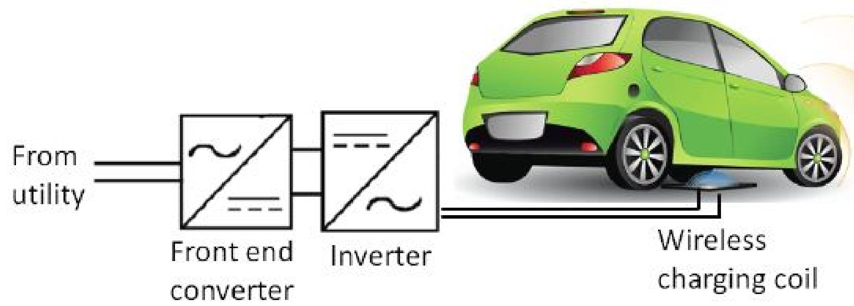
- Charging Stations, not gas stations
  - Will need to be built, or modify gas stations
- Current range of one full charge
  - Where is the next station?
    - Charging times – Currently long

Steven Kirby

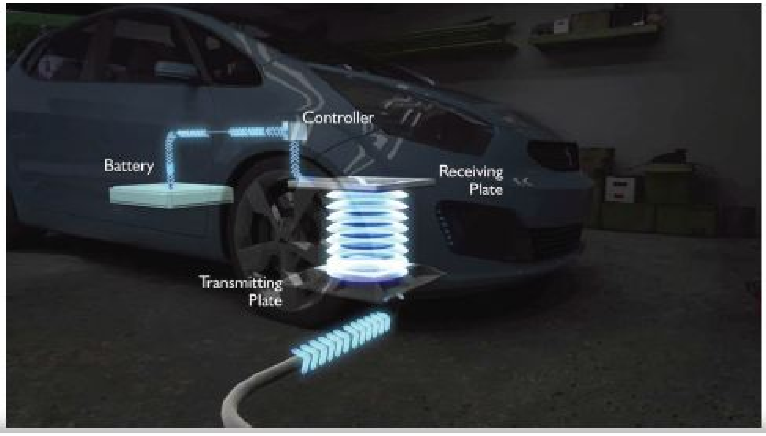
Challenges or R&D Focus for the Next 5-10 Years

Research and Development – Wireless Charge





Vehicle approaches charging pad, aligns and negotiates with WPTB station, commences charging

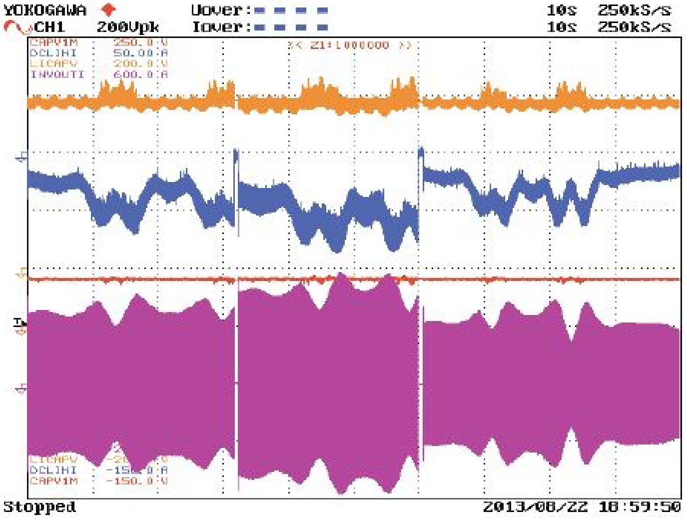


Research and Development – Wireless Charge

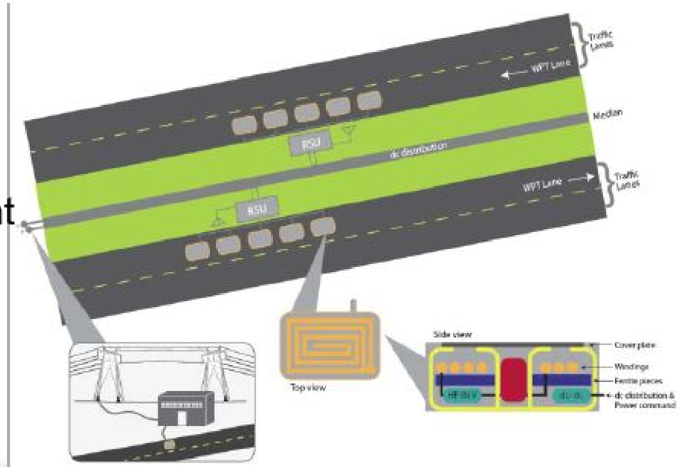
Dynamic Wireless Power Transfer (WPT) Experimental Results

- Illustration of system hardware
- Power flow as function of vehicle position

HF inverter system with HF transformer and self contained thermal management system



- Future directions in dynamic WPT
  - Infrastructure issues (roadway integrity)
  - Communications requirements (latency)
  - Grid power distribution (intermittency)
  - Coil sequencing and power modulation & alignment
  - Local energy storage (smoothening)
- Promote dc distribution along highway
- Highly distributed vs. centralized HF stage



Challenges

- Increased popularity of electric cars would put an increased load on the power grids.
- This demand if raised too rapidly would cause black outs.
- A house in San Francisco might only draw two kilowatts of power at times of peak demand, according to Pacific Gas & Electric. In comparison, a new electric vehicle on a dedicated circuit could draw 6.6 kilowatts.
- The grids would need to be upgraded prior to demand spike to avoid catastrophe.

Challenges

- A major challenge for electric car is energy storage.
- One challenge in this area is physical storage space of energy as batteries are large and more power means more batteries making the vehicles larger and heavier compounding the problem.
- Another challenge is safe and reliable rapid charging of batteries which hold dangerous chemical and run the risk of spilling and even exploding.

Yalong Li

True Stories of its Application or Demonstration

Application – Not Successful Story

- **General Motors EV1 (1996-2003) – First mass-produced and purpose-designed EV from a major auto maker**
  - **Background:** 1. Favorable reception for its electric concept car; 2. mandate of zero-emission vehicles from California government
  - **Reaction:** 1. Customers were positive; 2 GM believed that EV1 was unprofitable car
  - **Ending:** 1. All cars are repossessed; 2. Cost over $1 billion in total for 1160 produced EV1

Application – Successful Story

- **Tesla motors (2003-) – One of the most promising electric vehicle company**
  - **Background:** 1. Several main auto companies stopped EV program in 2003; 2. A few wealthy people still prefer to have an EV
  - **Reaction:** Both the two delivered EV models (Roadster and Model S) achieves a huge success in the market
  - **Future:** 1. Extend car models; 2. Mass-producing fully electric vehicles at a price affordable to the average consumers

Demonstration – Successful Story

- EV built in the Delft University of Technology – World's fastest accelerating electric vehicle ever
  - World's new record of 2.13s from 0-100 km/h; compared to the old record of 2.3s for production cars and 2.68s fro EVs
  - Four electric motors with a total power output of around 135 horsepower
- It proves that EV can out-muscle internal combustion engine cars

Mohammad Raoufat

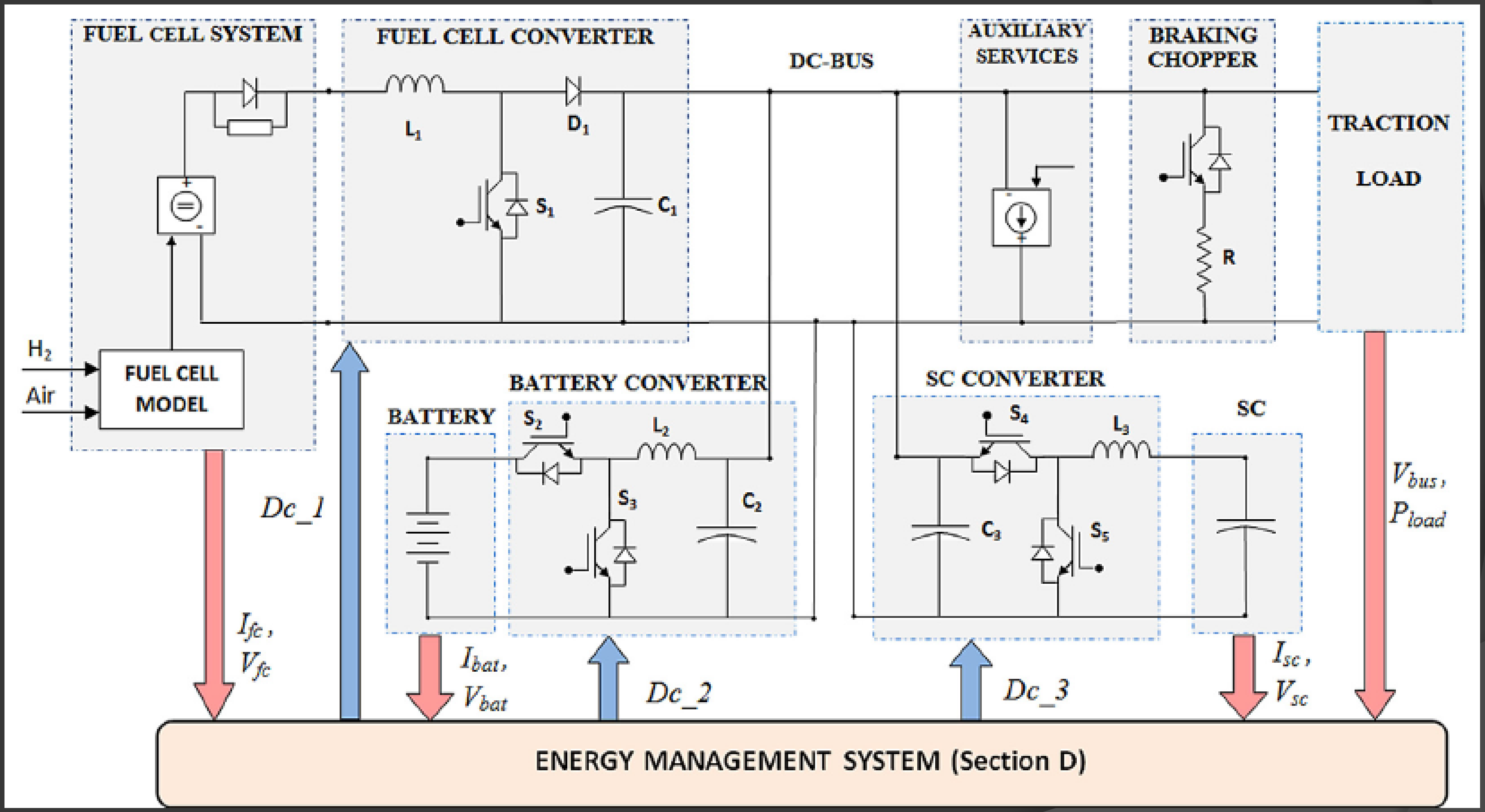
Related Research Papers Published in the Past 5 years

Control strategies for electric vehicles

- Fuel Cells (FCs) disadvantages:
  - ✓ Low power density
  - ✓ Slow startup and slow power response
  - ✓ Lower efficiency at low and high output power
  - ✓ Increasing the cost

- These drawbacks can be reduced by combining FCs with other energy storage systems:
  - Batteries
    - ✓ Provide power for longer period
  - Super capacitors (SC)
    - ✓ More efficient
    - ✓ Longer life time (Charge/ discharge cycles)

Control strategies for electric vehicles



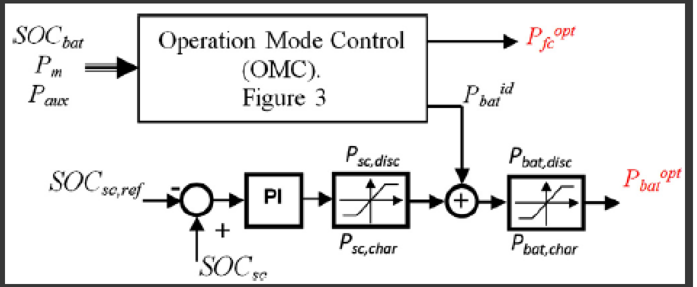
Control strategies for electric vehicles

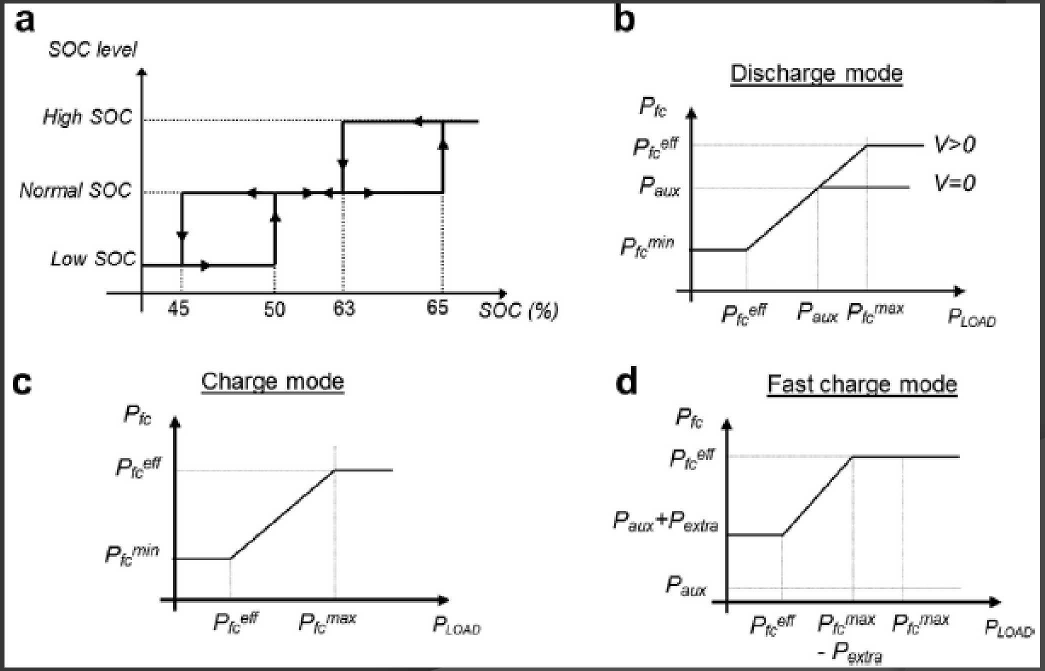
- The energy Management system is responsible for:
  - Controlling the system operation
  - Providing the power needed
  - Optimize the energy generated
  - Control the battery and SC

- Constraints and limitations:
  - FCs output power is kept between (p_{fc}^{max}, p_{fc}^{min})
  - FCs dynamic response is limited in slope
  - Battery power and current ($p_{Bat,char}^{max}$, $p_{Bat,disc}^{max}$) & ($I_{Bat,char}$,$I_{Bat,disc}$)
  - The dynamic limitation of the battery
  - The battery and SC are kept around their reference
  - …

Control strategies for electric vehicles

- Operating Mode Control (OMC)
  - OMC generates the FC and battery reference powers





Questions ?