Electric cars: Technology

Lecture notes: Lecture 2.1

Isolation between EV battery and grid

Lead acid batteries

This is a mature technology where limited progress has been made in terms of energy and power density. Deep cycle batteries are available, which have re-enforced electrodes to avoid separation and sludge formation[1]. Prospects for use in EVs are limited, due to low energy densities, sensitivity to temperature and life cycle[2].

Nickel based batteries

Nickel-metal hydride (NiMH) batteries are used extensively for traction purposes, and are optimized for high energy content. Nickel-cadmium (NiCd) batteries also show good potential for high specific energy and specific power, although the presence of cadmium has raised some environmental concerns[3].

High temperature batteries

Sodium-nickel chloride (NaNiCl or Zebra) batteries have been deployed in numerous EV applications to date[4]. The high specific energy is attractive for long range EVs. The high operating temperature (300°C) requires pre-heating before use, which can use quite a lot of energy if parked regularly for long periods. For this reason, this battery is considered more suitable to applications where the EV is being used continuously (public transport and delivery vans etc.).

Metal air batteries

Aluminum-air (Al-air) and zinc-air (Zn-air) batteries both use oxygen absorbed from the atmosphere on discharge and expel oxygen when being charged. The energy density of these batteries is high but, lower power densities mean that applications are limited. Al-air batteries consume the aluminum electrode, and must be removed and replaced or reprocessed. Some applications have been tested where fleets of EV delivery vehicles are running with Zn-air batteries, where removable zinc cassettes can be replaced when discharged for recharged units. The low specific power of metal air batteries may see these battery types restricted to long distance delivery vehicles, but the advantages of regenerative braking may be sacrificed.

Lithium based batteries

Lithium based batteries are classified by the type of active material. Two main types exist, those with liquid (Li-ion-liquid) and those with polymer electrolyte (Li-ion-polymer). The Li-ion-liquid type is generally preferred for EV applications. Within the Li-ion-liquid type, there are three lithium materials, lithium cobalt, (or lithium manganese oxides), lithium iron phosphate and lithium titanate.

Lithium manganese

Lithium manganese ($LiMn_2O_4$) offers a potentially lower cost solution. It has been largely studied for electrical vehicle application, especially in Japan. The drawback of this type of battery is the poor battery life due to the slight solubility of Mn.

Lithium iron phospate

Lithium iron phosphate (LiFePO$_4$) batteries are manufactured by many companies in the world and have gained credibility through their use in power tools. Lithium iron phosphate cells have a much lower energy density than standard format cells, but can be charged much faster—around twenty to thirty minutes. Moreover, LiFePO$_4$ has been recently considered that it features an improve stability on overcharge which is good for safety, a very high power and has potential for lower cost because they use iron.

Lithium titanate

Lithium titanate allows charging on the order of ten minutes and have been shown to have an extremely long cycle life - on the order of 5000 full depth of discharge cycles. Lithium titanate has high inherent safety because the graphite anode of two other batteries is replaced with a titanium oxide.

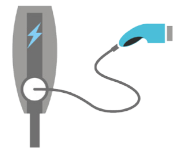
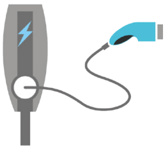


Table: Qualitative Comparison of EV Batteries[5]

1=poor; 2=fair; 3=good

Attribute	Lead-acid	Ni-MH	ZEBRA	Metal-air	Li-ion
Specific energy ($kWhkg^{-1}$)	1	2	3	3	3
Specific power ($kWkg^{-1}$)	1	3	1	1	3
Capacity (kWh)	1	2	3	3	3
Discharge power (kW)	3	2	2	1	3
Charge power (kW)	1	2	2	1	3
Cold temperature performance (kW and kWh)	3	2	3	2	1
Shallow cycle life	2	3	1	1	3
Deep cycle life	1	3	1	1	2
Cost (€kW^{-1} or €kWh^{-1})	3	1	1	1	1
Abuse tolerance	3	3	2	2	2
Maturity technology	3	3	2	2	2
Maturity manufacturing	3	1	2	2	1
Recyclability [70]	1	1	3	2	2



References

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2. Westbrook, M.H., *The Electric Car: Development and future of battery, hybrid and fuel-cell cars.* IEE Power Series no. 38. 2001
3. Van den Bossche, P., et al., SUBAT: *An assessment of sustainable battery technology*. Journal of Power Sources, 2005. 162(2)
4. Resmini, F. and J. Ohlson, *ZEBRA battery integration in "Think City" pure battery electric vehicle*, in EVS24. 2009: Stavanger, Norway
5. Adapted from Pistoia, G., *Battery Operated Devices and Systems*, 2009 Elsevier