A Study on Electric Vehicle Battery Life Optimisation

Ashish Shahane[1], Amol Shahane[2], Chinmay Kodle[2], Dattatraya Lawate[3]
[1]*Student, SVERI's College of Engineering, Pandharpur, Maharashtra, India*
[2]*Student, St. Mary's College of Engineering and Technology, Hyderabad, Telangana, India*
[2]*Student, Kai. Brahmdevdada Mane Institute of Technology, Solapur, Maharashtra, India*
[3]*Assistant Professor, Smt. Kashibai Navale College of Engineering, Vadgaon, Pune, Maharashtra, India*

***Abstract*. Electric vehicle technology is now emerging rapidly and the use of batteries for this purpose is also increasing consistently. Battery life optimisation is one of the most important factors to be considered to make the electric vehicles economical to use these days. Recycling, reuing, battery materials and temperature considerations play a vital role in a battery life optimization. A detailed review is presented herein on electric battery life optimisation by taking some of the factors mentioned above into considerations.**
***Keywords*. EV Battery, Anode Material, Li-ion Battery, Battery Temperature, Battery Recycling, 2nd Life of Batteries.**

I. Introduction

There is no doubt that the automotive gasoline vehicle technology in the future is going to be replaced by the electronic vehicle (EV) technology. The electric vehicle technology is now in full force, with established brands committing offering a wider range of pure electric cars in the future. This, in turn, increases the demand of EV batteries. Hence it is necessary to make the EV batteries robust in its usage. EV batteries are designed to give power over sustained periods of time. Hence they differ from starting, lighting, and ignition batteries. EV batteries are usually designed with a high ampere-hour capacity. There are various characteristics to be considered for EV batteries such as power-to-weight ratio, energy density and specific energy. Also compact and lightweight batteries reduce the weight of the vehicle and improve its performance. The cathode in the metal-air battery has high specific energy because it is provided by the surrounding oxygen in the air. Batteries such as lead-acid, NiCd, nickel-metal hydride, lithium-ion, Li-ion polymer, and, less commonly, zinc-air and molten-salt batteries are used in the electric vehicles which are rechargeable. Lithium-ion and Lithium polymer battery is best suitable for emerging electric cars. This is because of their high energy density compared to their weight.

With this rising technology, batteries are in higher demand. But there needs to be a lot of improvement in various sectors of battery technology to make it economical to use today. Problems such as frequent charging, the low voltage due to varying climatic changes, low mileage in electric car, low battery life are being faced by an electric vehicle these days. A sense of environment friendliness should also be taken into consideration while manufacturing of the batteries as it contains a lot of harmful chemicals which are having undisposable properties.

II. Literature Survey

Samvex Saxena et al. [1] states that EV batteries can be used well beyond their retirement. The author states that the retirement threshold of EV batteries with 70-80% of their capacity is overly consective. The article conclusively shows that even beyond the threshold capacity the batteries continue to meet the daily needs of drivers. The author also suggests that the useful life of the batteries can be improved by enabling charging in more locations. Based on results the article proposes that battery retirement should be defined to occur when a battery can no longer meet the daily travel need of the driver. A great deal of prior analysis has assumed that EV batteries are retired at 70-80% of remaining capacity and this article conclusively shows that this is an incorrect retirement threshold. The author finally concludes that degraded batteries can continue to meet the daily travel need of the drivers who have shorter range trips. Jungsoo Kim et al. [2] have proposed a multilayer perception (MLP) algorithm for a state of health (SOH) of a battery instead of using SOH with the battery management system (BMS) of an EV. The article states that the experimental data for the whole lifetime of a battery, and adopt standard charging and discharging pattern does not reflect the real world driving pattern. This gives the reason to author to use MLP. Based on the expectation analysis of classification results, it is shown that the SOH estimation is well performed in both trained life span and untrained life span. When the algorithm of this work is applied to the BMSof an EV, it is expected that users will be provided with the health information of the battery at any time while driving. Rui Xiong et al. [3] have explained all the detailed classification of battery SOH estimation. The article also highlights the strengths and weakness of SOH methods. Deficiencies of the existing research and improving directions are pointed out. SOH estimation with ultrasonic is expected to add one-dimensional data to batteries. Comparison of direct measurement methods, indirect analysis methods, and adaptive filtering methods and data driving method of SOH estimation is made. The author also suggests that in future advanced sensing, big data and data mining and multiagent decision-making techniques will be used to determine the SOH for batteries. Ron Adany et al. [4] have developed a switching algorithm for a penalty function to measure the negative effects of discharge in optimal discharge currents. These algorithms are evaluated by the author on world-wide driving cycles by simulating and the preferences are compared with the common discharge method. The results show that the proposed algorithms significantly decrease the total penalty, and for some configurations almost eliminate it. Hence, the battery's life can be extended significantly by the proposed algorithms in comparison to the common discharge method. G. Benveniste et al. [5] states that most commonly used Lithium-ion (Li-ion) batteries in Evs can be replaced by Lithium-Sulphur (Li-S) to get better results and to overcome all the laggings of Li-ion batteries. The article states that Li-S batteries are better qualified than Li-ion batteries in various factors such as safety (better), price (lower) and environmental impact (lower). The auther posits that Li-ion batteries used in EVs are reaching its theoretical limit (200-250 Wh/kg). He says that all this lacunas can be solved by the use of Li-S batteries in future Evs. Junghoon Lee et al. [6] have developed a dual battery management scheme to integrate renewable energy. He states that dual battery can elevate the intermittency of renewable energy with an efficient scheduling mechanism. Ephrem Chemali et al. [7] have used Deep Feedforward Neutral Networks (DNN) to estimate battery accurate State of Charge (SOC). The results from extensive validation tests shown in this article illustrates that the DNN offers competitive estimation performance. As a result, it is concluded that machine learning techniques are powerful tools when applied to Li-ion battery SOC estimation and potentially to other battery diagnostics. Datong Liu et al. [8] has introduced an online life cycle health state assessment in a battery management system. He has introduced the KPCA algorithm to fuse the battery degradation features. Considering complex conditions in EVs Li-ion battery cell is tested under the DST conditions. The GRA value of the fused degradation feature is 0.768 and the ε_{MA} of the capacity estimation is only 11.5630 mAh. This method proposes that this method can be applied in EV application with high accuracy and robustness.

III. Battery Materials

Most electric vehicle batteries are lithium based and rely on a mix of cobalt, manganese, nickel, and graphite and other primary components. Using appropriate anode material also increases the efficiency of Li-ion batteries. According to Taohua Huang et al. [9], using 2D semiconducting borophene (JACS, 2017, 139, 17233) as an anode material for batteries like Li-ion and Na-ion increases efficiency in various aspects. The article shows that by using this kind of anode material provides larger Li/Na adsorption energies (− 1.62 eV for Li and− 1.41 eV for Na) by avoiding the formation of dendrites. According to the calculations, the anode material also provides with low diffusion energy (− 1.62 eV for Li and− 1.41 eV for Na) which ensures easy transportation of Li/Na atoms to the surface.

Graphite as anode material for sodium-ion batteries (SIBs) according to M.R. Al Hassan et al. [10], it shows amazing superlative properties which can be demonstrated by the table given below.

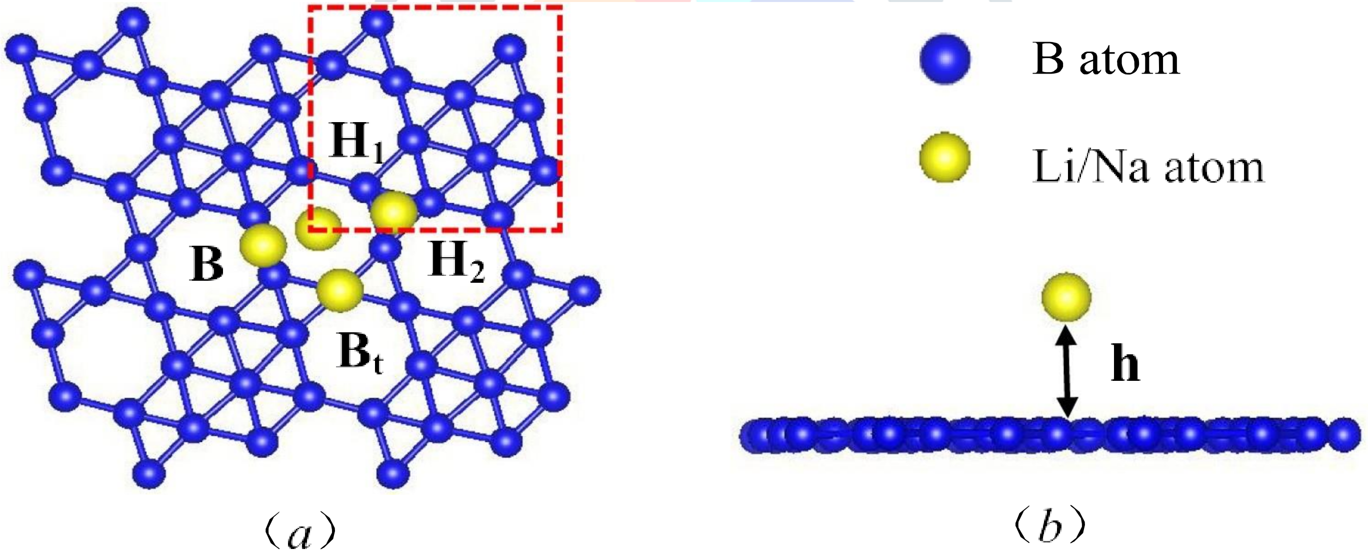


Fig. 1 Possible Adsorption sites of Li/Na Atom on s: Top View (a) Side View (b). Red Region is the Unit Cell and h is the Height of Adsorption [9].

TABLE I
Graphene-Based Few Anode Materials and their Electrochemical Performances for SIBs [10].

Compound	Specific capacity and cyclic stability	Rate capability	Synthesis technique	Year	Ref.
rGO	First discharge capacity around 780 $mAhg^{-1}$ at 200 mAg^{-1}. After 250 cycles 93.3 $mAhg^{-1}$	174 $mAhg^{-1}$ at 40 mAg^{-1}, 93 $mAhg^{-1}$ at 200 mAg^{-1}	Modified Hummers' method	2013	[11]
GNS	First discharge capacity 250 $mAhg^{-1}$ at 30 mAg^{-1}. After 300 cycles 200 $mAhg^{-1}$	220 $mAhg^{-1}$ at 30 mAg^{-1}, 105 $mAhg^{-1}$ at 5000 mAg^{-1}	GO reduction and exfoliation	2015	[12]
SnO_2/G	First discharge capacity 1942 $mAhg^{-1}$ at 20mAg^{-1}. After 100 cycles 638 $mAhg^{-1}$	569 $mAhg^{-1}$ at 40 mAg^{-1}, 263 $mAhg^{-1}$ at 320 mAg^{-1}	Hydrothermal	2013	[13]
SnS_2/G	First discharge capacity 1339 $mAhg^{-1}$ at 20mAg^{-1}. After 60 cycles 670 $mAhg^{-1}$	478 $mAhg^{-1}$ at 40 mAg^{-1}, 214 $mAhg^{-1}$ at 320 mAg^{-1}	Hydrothermal	2014	[14]
CoS/rGO	First discharge capacity ~680 $mAhg^{-1}$ at 100 mAg^{-1}. After 60 cycles 630 $mAhg^{-1}$	636 $mAhg^{-1}$ at 100 mAg^{-1}, 359 $mAhg^{-1}$ at 5000 mAg^{-1}	Solvothermal	2016	[15]
N-doped rGO aerogel	First discharge capacity 1019 $mAhg^{-1}$ at 100 mAg^{-1}. After 200 cycles 287.9 $mAhg^{-1}$	300 $mAhg^{-1}$ at 100 mAg^{-1}, 152 $mAhg^{-1}$ at 5000 mAg^{-1}	Hydrothermal	2017	[16]

MoS_2/G	First discharge capacity 797 $mAhg^{-1}$ at 0.2 Ag^{-1}. After 600 cycles 322 $mAhg^{-1}$ at 1.5 Ag^{-1}	427 $mAhg^{-1}$ at 1 Ag^{-1}, 234 $mAhg^{-1}$ at 10 Ag^{-1}	Ultrasonic spray pyrolysis	2015	[17]
SnS/N-doped G	First discharge capacity 1099.8 $mAhg^{-1}$ at 0.1 Ag^{-1}. After 1000 cycles 509.9 $mAhg^{-1}$ at 2 Ag^{-1}	913 $mAhg^{-1}$ at 100 mAg^{-1}, 405 $mAhg^{-1}$ at 6000 mAg^{-1}	Hydrothermal	2017	[18]
Phosphorus/G	First discharge capacity 2077 $mAhg^{-1}$ at 260mAg^{-1}. After 60 cycles around 1700 $mAhg^{-1}$	1700 $mAhg^{-1}$ at 520 mAg^{-1}, 750 $mAhg^{-1}$ at 2600 mAg^{-1}	Ball milling	2014	[14]
CoS/rGO	First discharge capacity 756 $mAhg^{-1}$ at 100 mAg^{-1}. After 30 cycles 346 $mAhg^{-1}$	441 $mAhg^{-1}$ at 100 mAg^{-1}, 307 $mAhg^{-1}$ at 500 mAg^{-1}	Solution mixing and evaporation	2017	[19]
RPQDs/rGO	First discharge capacity 1145 $mAhg^{-1}$ at 200 mAg^{-1}. After 250 cycles 900 $mAhg^{-1}$	902 $mAhg^{-1}$ at 200 mAg^{-1}, 193 $mAhg^{-1}$ at 4000 mAg^{-1}	Solution mixing, hydrazine reduction	2017	[20]
N-doped C/G	First discharge capacity 855 $mAhg^{-1}$ at 100 mAg^{-1}. After 300 cycles 509 $mAhg^{-1}$	582 $mAhg^{-1}$ at 200 mAg^{-1}, 501 $mAhg^{-1}$ at 3200 mAg^{-1}	Solution mixing and pyrolysis	2014	[21]
In_2S_3/G	First discharge capacity 852 $mAhg^{-1}$ at 200 mAg^{-1}. After 60 cycles 550 $mAhg^{-1}$	620 $mAhg^{-1}$ at 200 mAg^{-1}, 335 $mAhg^{-1}$ at 5000 mAg^{-1}	Solvothermal and annealing	2017	[22]

G, graphene; GNS, graphene nanosheet; RPQD, red phosphorus quantum dot; rGO, reduced graphene oxide.

Along with these materials, organic battery electrode materials (OBEMs) can be designed to offer unique features compared to other anode materials. OBEMs are amongst the most promising cathode materials to achieve the 500 Wh kg^{-1} specific energy target for EV batteries as compared with the working potential and specific capacity of inorganic intercalation compounds (IICs) and sulfur [23]. Also along with anode materials, binders also play a major role in increasing the efficiency of the EV batteries. Yue Ma et al. [24] states binders as a “neutral network” which connects the electrode and provides a pathway to the entire electrode matrix. The article also states that in the presence of oxide species including KO_2 and Li_2O_2 in Li-O_2 battery the traditional polymer binder is chemically stable which leads to the conclusion that both electrochemically and chemically stable species must be used in Li-O_2 batteries.

IV. Temperature Constraints

While utilization of portable types of equipments or electric vehicles, lithium-ion batteries have presently no competitor in terms of life solidity or durability. Most of the applications that stand in need of high power rechargeable batteries that can perform at a high temperature (>100 °C) but there is a limited temperature range of -25 °C to 60 °C [25]. In new energy vehicles and power grids due to their high current discharge, compact size, long service life, and maintenance free the lithium iron phosphate batteries have been extensively used as comparatively close to the present years [25, 26]. Correspondingly [26], it is essential to study the battery designing and the SOC assessment arrangement at low temperature, which is of tremendous suggestions for a battery to execute attentively and increase the battery power accomplishment under various temperature conditions.

SOC Estimation at Low Temperature: For calculating the mileage of new energy electric vehicles and modern energy terms the battery state of charge (SOC) criteria plays an important role. The system parameters of the i^{th} SOC element points to the open circuit voltage of different SOC points is as follows.

$$Hi = OCV(i) - OCV(i-1)\ / SOC\ (i) - SOC\ (i-1)$$

Where, SOC = State of Charge, OCV = Open Circuit Voltage, i-th = Parameter of i^{th} SOC feature points, H = Kalman filter algorithm.

Here only ‘H’ is calculated with the known temperature and SOC points, for unknown temperature and SOC points, ‘H’ is still included from known points [26]. Device for EVs is lithium-ion (Li-ion) batteries as regarded because of their higher energy density, higher specific power, lighter weight, lower self-discharge rates, higher recyclability and longer cycle life than other rechargeable batteries such as lead-acid, nickel-cadmium (Ni-Cd), nickel-metal hydride (Ni-MH) batteries [27]. The SONY®US18650VTC5 batteries with a rated capacity of 2.5Ah and the initial SOC is assumed to be 50%, while the other OPTIUM®LiFePO4 batteries are rated capacity of 5Ah and the value is 80% [28].

TABLE II
Parameters of the LiFePO4 Battery Cell [29].

Parameter	Value
Nominal Voltage, Vnom (v)	3.2
Capacity, Qbat Cell (Ah)	60
Battery Cell Weight, Mbat Cell (kg)	2
Max Discharge Current (A)	+ or -540
Operating Temperature Window (c)	-20 to 45

At low temperatures, PHEVs suffer low battery performance. Li-ion batteries can experience significant capacity loss for several reasons:

1) The electrolyte becomes viscous and even partially solidified, which results in low ionic conductivity.

2) The compatibility between the electrolyte and electrode is deteriorated; 3) the cathode is delithiated and the anode is over-lithiated [29].

The advantages by Energy Management strategy due to the rapid response time the EV are requested to be met or recovered by the ultracapacitor for instantaneous power demand and the recoveries [30].

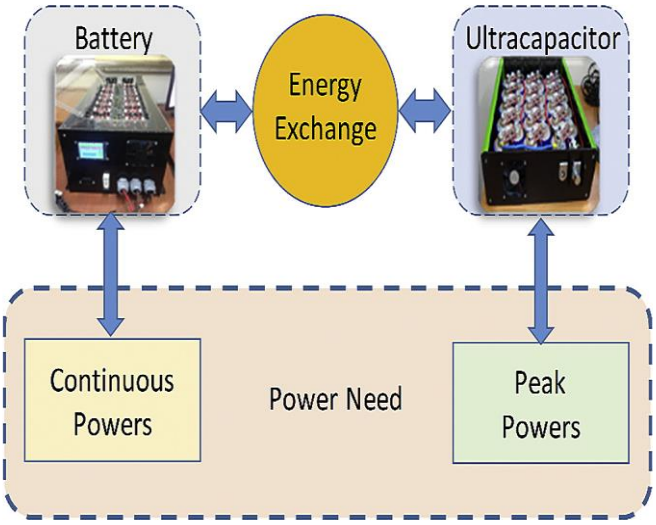


Fig. 2 General Power Sharing Scheme [30].

Li-ion batteries have chemical processes that are largely exothermic. The thermal management of Li-ion battery systems is critical to the success of all electric vehicles as the extreme temperature can affect performance, reliability, safety, and lifespan of electric vehicles [31]. By increased application of ready for using the energy even at low temperatures, which in turn no doubt increases it allows full improvement of developmental braking energy and the vehicle journey range by approximately 50% at −40 °C. At the point of driving, the vehicles would also be primed for fast recharging after driving with the battery remaining temperature high, near room temperature [32].

V. Battery Recycling

The present Lithium low prices it is economically damaging to repair due to ongoing industrial operations are focused on improving cobalt and new beneficial as well as profitable metals. Cells that were released to 0.5V formed small red flames and fumes, display a promising safety problem. To test whether setting free to 0.0V is indeed enough to open batteries in air LiCoO2 pouch cells were opened they had a theoretical capacity of 3.0 Ah, nominal voltage 3.7V, energy mass of 195 Wh/kg, and a weight of 57 g. Cells that were released to 0.0 V composed nor yet flames nor fumes nor did they show any documentation feedback. Opening in water outcome in an exothermic reaction and the production of hydrogen gas, which is hazardous. LIBs can be dismantled by automated processes which regain leftover energy, their cells can be laid off, which restore useful electronics for restating which restore important electronics for reuse [33].

Li-ion batteries have previously found usage in delicate operations, containing road-transport and aviation. Li-ion batteries contain lithium, oxygen and a flammable electrolyte at this time an installed technological challenge when it comes to safety. Li-ion batteries are transported daily on flights by passengers, in portable electronics. For detail through extended access charge or short circuiting to the level of decay its metal oxide, the Li-ion batteries are thermal escaped: if a battery cell is extremely heated could explosion into flames because of the reaction of released oxygen with lithium [34].

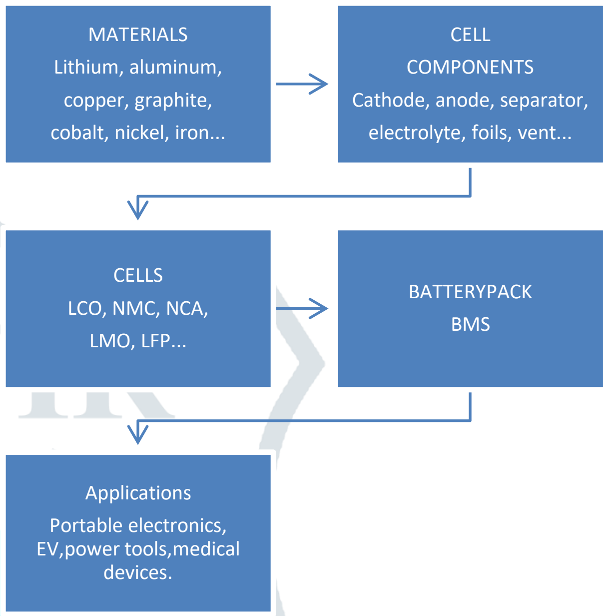


Fig. 3 Production Structure of Li-ion Battery Industry [34].

TABLE III
Projected Cumulative World Battery Material Demand to 2025 (1000 tons) [35].

Element	Projected Demand		USGS Reserves
	If all NMC is low-Co(811)	If all NMC is high-Co (111)	
Lithium	230	230	16,000
Cobalt	790	910	7,100
Nickel	580	340	74,000

At the same time, demand is wanted to carry on its fast growth due to large numbers of batteries will not be ready for use for recycling until 10–20 years after mass-market penetration, needing much more material than recycling could supply. Nevertheless, compressing costs and other force of destruction, and decreasing reliance on foreign materials provides additional benefits, including restraining unspoiled material prices.The ability to recycle through abate energy usage and emissions in EV battery production and the Life-cycle investigation of battery production and recycling processes has determined [35].

A total recycling procedure for LIBs generally needs two typical processes: physical processes and chemical processes. The physical processes consist of pretreatments, such as dismantling, crushing, screening, magnetic separation, washing, thermal pretreatment, etc. The chemical processes can be classified into pyrometallurgical processes and hydrometallurgical processes, in which leaching, separation, extraction, and chemical/electrochemical precipitation are usually involved [36]. The recovery methods of components on LIB cells, especially cathode materials, can be divided into hydrometallurgy, pyrometallurgy, biometallurgy, and combination methods. The flow diagram of the typical recycling process is shown in fig [37].

Fig. 4 Flow-Chart Showing Typical Recycling Process [37].

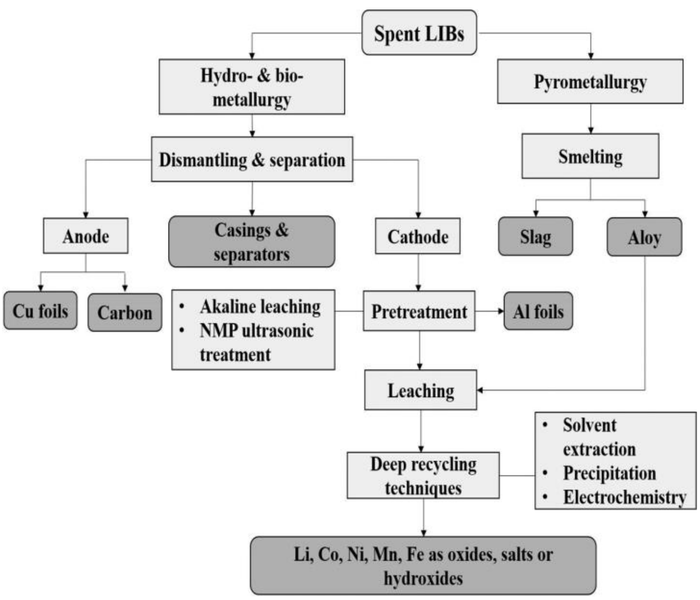
It occurs that Li_2CO_3 does not reach battery grade quality to open loop recycling where it is renewed, alternatively of primary Li_2CO_3 in basic demand sectors such as glass, glass-ceramics, ceramics, alloys, aluminum production the recycled material can be used. The closed-loop recycling is assumed, meaning that secondary Li_2CO_3 reaches a quality that allows its reuse in the fabrication of new Li-ion batteries for EV as well as non-automotive applications [38].

VI. Reuse of EV Batteries

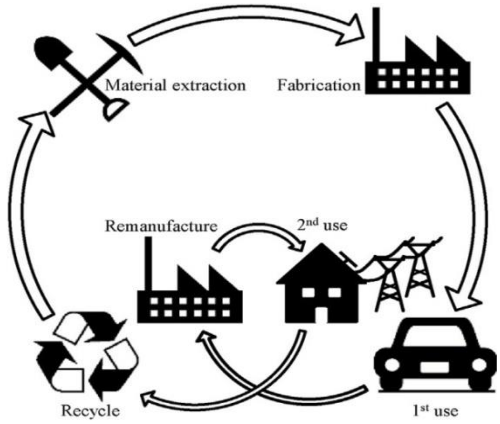
Reusing the EV battery is the best measure which can be taken to optimize its use. According to Lluc Canals Casals et al. [39], batteries can possess 80% capacity even after its eight or ten year's warranty period. As Li-ion batters are much expensive as compared to other batteries by taking the economic conditions in mind the Sunbatt project was originated which describes the applications as follows: Support to EV fast charge, self-consumption, and area regulation and, transmission deferral. Along with this battery rest of useful life (RUL) can endure up to 12 years by offering renewable electricity generation.

Fig. 5 Circular Economy of Re-Used Batteries [39].

As per S. Rohr et al. [40] exceeding critical limits like deep



discharge during battery life, non-linear change in capacity and increasing cell spreading is the major risk in lifetime prediction. Also according to this literature investigation

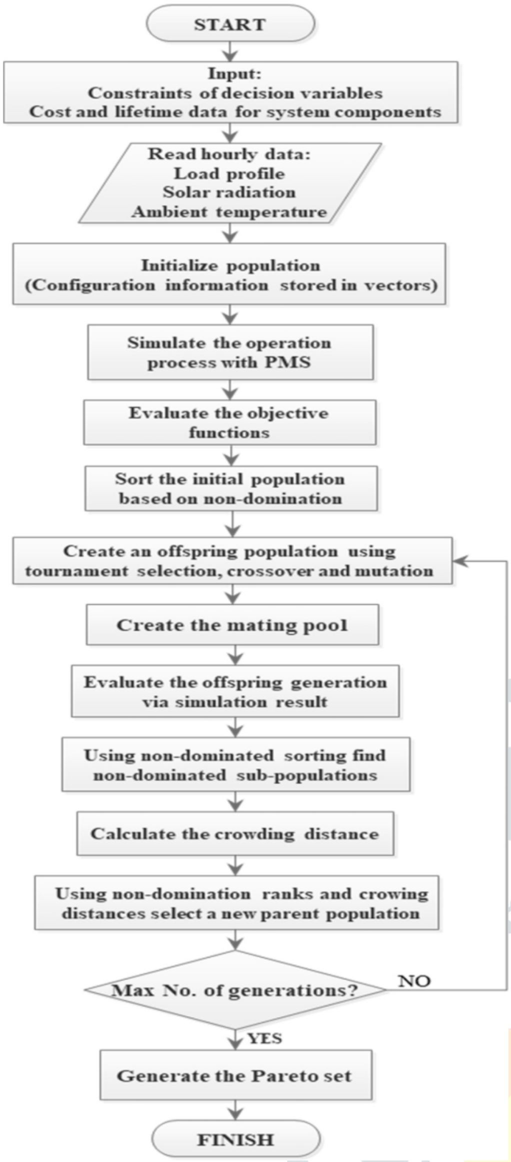


of linear cell aging and these uncertainties, up to battery pack level, helps in identifying correlations between operating conditions and the according to failure distribution. Also, applications of this article can be extended to real world automotive applications. However, the results of this article are just the starting point to reduce risk in reusing Li-ion batteries.

Brilliant work by Zhiyu Huang et al. [41] is done in optimizing stand-alone PV-hydrogen-retired battery hybrid energy system. This article is about the reusing of the retired electric vehicle batteries (REVBs) and discusses the design and sizing optimization of the entire system. It focuses on three aspects, firstly, the model of capacity fading of Li battery cells which gives space for the more realistic result for design. Secondly, the article has proposed a fantastic power management property to regulate the energy flow to protect the REVB. Thirdly, multiple objectives like including minimizing loss of power supply, new indicator (potential energy supply) and system cost are considered. One of the interesting facts about the article is that it includes the usage of NSGA-II algorithm to generate the Pareto set of a case for residual usage. This can be demonstrated by the following flow chart.

Fig. 6 Framework of the Optimization Design Using NSGA-II [41].

Mattia Barbero et al. [42] states that second life EV battery has interesting markets. The case study combines the knowledge of battery aging process and economic analysis. The study by the author shows that the lifespan of the EV batteries can be increased by 35% by including its 2nd life use in building applications. Also, the study reviles that the aging of the battery can be beneficial in the final results, by indicating the participation of FCR markets which reduces the amortization costs of the battery by maintaining the economic incomes due to the reduction of aging per kWh delivered (aging/cycle).



VII. Conclusion

In this review an extensive study is done which deals with different anode materials along with binders. An extensive study is done by various authors to study the increase in absorption capacity of the batteries by using different anode materials. A brief study is also mentioned in this review by using graphite and organic components as anode materials.

To lengthen and upgrade the thermal tolerance of Li-ion batteries performing at higher temperatures will need much extra research specifically because most of the studies don't interrogate temperatures exceeding 60 ˚C. Article also posits the studied method for judging SOC using a Kalman filtering algorithm at low temperature. Categorization of the current BTMS studies according to its thermal cycle options and the BTMS using VCC has been used to most of the EVs because of its benefits of making use of current AC systems to cool or heat the battery. The article also states the heating necessities of PHEVs at sub-zero temperatures and important reasons for the capacity loss. The method of self-heating while driving is found to be very energy-effective and fast, with the heating energy supplied from both stored battery energy and vehicle braking energy. The present industrial processes of recycling Li-ion batteries do not restore enough amount of lithium to meet forecast appeal from automotive Li-ion battery manufacturers. Within the entire simple cost decline are required to permit a continous speed upmarket production particularly for EV, and an extending territory of applications, most particularly the use of Li-ion batteries in power supply systems. Their recycling would have environmental and confidentially economic profits, but none of the various methods for their recycling is perfect, each has its own disadvantages and advantages. With the boom of EVs in the world and scarcity of raw material of lithium ion battery, the methods to solve the recycling problem will be a big challenge in the near future. A brief literature study also shows that reusing the EV batteries is not only a good factor considering environmental issues but also makes EV batteries very economical. According to the literature review EV batteries can endure up to 12 years in its 2nd life and can be used in building and renewable energy generation applications.

REFERENCES

[1] Samveg Saxena, Caroline Le Floch, Jason MacDonald, Scott Moura, *Quantifying EV battery end-of-life through analysis of travel needs with vehicle powertrain models*. Power Sources 282 (2015) 265-276.

[2] Jungsoo Kim, Jungwook Yu, Minho Kim, Kwangrae Kim, Soohee Han, *Estimation of Li-ion Battery State of Health based on Multilayer Perceptron: as an EV Application*. IFAC PapersOnLine 51-28 (2018) 392–397.

[3] Rui Xiong, Linlin Li, Jinpeng Tian, *Towards a smarter battery management system: A critical review on battery state of health monitoring methods*. Power Sources 405 (2018) 18–29.

[4] Ron Adan, Doron Aurbach, Sarit Kraus, *Switching algorithms for extending battery life in Electric Vehicles*. Power Sources 231 (2013) 50e59.

[5] G. Benveniste, H. Rallo, L. Canals Casals, A. Merino, B. Amante, *Comparison of the state of Lithium-Sulphur and Lithium-ion batteries applied to electromobility*. Journal of Environmental Management (2018), doi: 10.1016/j.jenvman.2018.08.008.

[6] Junghoon Lee, Gyung-Leen Park, *Dual battery management for renewable energy integration in EV charging stations*. Neurocomputing 148 (2015) 181 –186.

[7] Ephrem Chemalia, Phillip J. Kollmeyera, Matthias Preindlb, Ali Emadi, *State-of-charge estimation of Li-ion batteries using deep neural networks: A machine learning approach*. Power Sources 400 (2018) 242–255.

[8] Liu D, Song Y, Li L, Liao H, Peng Y, *On-line life cycle health assessment for lithium-ion battery in electric vehicles*, Journal of Cleaner Production (2018), doi: 10.1016/j.jclepro.2018.06.182.

[9] Taohua Huang, Binwei Tian, Jiyuan Guo*, Huabin Shu, Ying Wang, Jun Dai, *Semiconducting borophene as a promising anode material for Li-ion and Na-ion batteries*. Materials Science in Semiconductor Processing 89 (2019) 250–255.

[10] M.R. Al Hassan, A. Sen, T. Zaman, M.S. Mostari, *Emergence of graph ene as a promising anode material for rechargeable batteries: a review*. Materials Today Chemistry 11 (2019) 225 e243.

[11] Y.X. Wang, S.L. Chou, H.K. Liu, S.X. Dou, *Reduced graphene oxide with superior cycling stability and rate capability for sodium storage*. Carbon 57 (2013) 202 e208.

[12] X.F. Luo, C.H. Yang, Y.Y. Peng, N.W. Pu, M.D. Ger, C.T. Hsieh, J.K. Chang,*Graphene nanosheets, carbon nanotubes, graphite, and activated carbon as anode materials for sodium-ion batteries*. J. Mater. Chem. A3 (19) (2015)10320 e10326

[13] D. Su, H.J. Ahn, G. Wang, *SnO2@ graphene nanocomposites as anode materials for Na-ion batteries with superior electrochemical performance*. Chem.Commun. 49 (30) (2013) 3131 e3133.

[14] X. Xie, D. Su, S. Chen, J. Zhang, S. Dou, G. *Wang, SnS2 nanoplatelet@ graphene nanocomposites as high capacity anode materials for sodium ion batteries*. Chem. Asian J. 9 (6) (2014) 1611 e1617.

[15] S. Peng, X. Han, L. Li, Z. Zhu, F. Cheng, M. Srinivansan, S. Ramakrishna, *Unique cobalt sulfide/reduced graphene oxide composite as an anode for sodium ion batteries with superior rate capability and long cycling stability*. Small 12(10) (2016) 1359 e1368.

[16] Zhang, C. Li, Z. Peng, Y. Liu, J. Zhang, Z. Liu, D. Li, *3D free-standing nitrogendoped reduced graphene oxide aerogel as anode material for sodium ion batteries with enhanced sodium storage*. Sci. Rep. 7 (1) (2017) 4886.

[17] S.H. Choi, Y.N. Ko, J.K. Lee, Y.C. Kang, *3D MoS2 egraphene microspheres consisting of multiple nanospheres with superior sodium ion storage properties*. Adv. Funct. Mater. 25 (12) (2015) 1780 e1788.

[18] X. Xiong, C. Yang, G. Wang, Y. Lin, X. Ou, J.H. Wang, K. Huang, *SnS nanoparticles electrostatically anchored on three-dimensional N-doped graphene as an active and durable anode for sodium-ion batteries*. Energy Environ. Sci.10 (8) (2017) 1757 e1763.

[19] G. Zhan, Z. Lin, B. Xu, B. Yang, X. Chen, X. Wang, J. Liu, *Cobalt sulfide-reduced graphene oxide nanohybrid as high-performance sodium ion battery anode,J. Mater. Sci. Mater. Electron*. 28 (18) (2017) 13710 e13715.

[20] J. Qian, X. Wu, Y. Cao, X. Ai, H. Yang, *High capacity and rate capability of amorphous phosphorus for sodium ion batteries*. Angew. Chem. 125 (17) (2013) 4731 e4734.

[21] Y. Zhang, P. Zhu, L. Huang, J. Xie, S. Zhang, G. Cao, X. Zhao, *Few layered SnS2 on few layered reduced graphene oxide as Na ion battery anode with ultralong cycle life and superior rate capability*. Adv. Funct. Mater. 25 (3) (2015) 481 e489.

[22] X. Wang, J.Y. Hwang, S.T. Myung, J. Hassoun, Y.K. Sun, *Graphene decoratedby indium sulfide nanoparticles as high-performance anode for sodium-ionbatteries*, ACS Appl. Mater. Interfaces 9 (28) (2017) 23723 e23730.

[23] Yanliang Liang and Yan Yao, *Positioning Organic Electrode Materials in the Battery Landscape*. Joule 2, 1690–1706, September 19, 2018 1691.

[24] Yue Ma, Jun Ma and Guanglei Cui, *Small things make big deal: Powerful binders of lithium batteries and post-lithium batteries*. Energy Storage Materials, https://doi.org/10.1016/j.ensm.2018.11.013.

[25] Daniel R. Wright, Nuria Garcia-Araez, John R. Owen, *Review on high temperature secondary Li-ion batteries*. Energy Procedia 151 (2018) 174–181.

[26] Jian Wu, Tong Li, Hao Zhang, Yanxiang Lei, Guangquan Zhou, *Research on Modeling and SOC Estimation of Lithium Iron Phosphate Battery at Low Temperature*. Energy Procedia 152 (2018), Shanghai, China.

[27] J. Kim, J. Oh, H. Lee, *Review on Battery Thermal Management System for Electric Vehicles*. Applied Thermal Engineering (2018), doi: https://doi.org/10.1016/j.applthermaleng.2018.12.020 .

[28] Xiaopeng Tang, Yujie Wang, Changfu Zou, Ke Yao, Yongxiao Xia, Furong Gao, *A novel framework for Lithium-ion battery modeling considering uncertainties of temperature and aging*. Energy Conversion and Management 180 (2019) 162–170.

[29] Tianze Wang, Xiaogang Wua, Shaobing Xu, Heath Hofmann, Jiuyu Du, Jianqiu Li, Minggao Ouyang, Ziyou Song, *Performance of plug-in hybrid electric vehicle under low temperature condition and economy analysis of battery pre-heating*. Power Sources 401 (2018) 245–254.

[30] Akif Demircal, Peter Sergeant, Selim Koroglu , Selami Kesler, Erkan Oztürk, Mustafa Tumbek, *Influence of the temperature on energy management in battery-ultracapa citor electric vehicles*. Journal of Cleaner Production 176 (2018) 716e725.

[31] L.W. Jin a, P.S. Lee, X.X. Kong, Y. Fan a, S.K. Chou, *Ultra-thin minichannel LCP for EV battery thermal management*. Applied Energy 113 (2014) 1786–1794.

[32] Guangsheng Zhang, Shanhai Ge, Xiao-Guang Yang, Yongjun Leng, Dan Marple, Chao-Yang Wang, *Rapid restoration of electric vehicle battery performance while driving at cold temperatures*. Power Sources 371 (2017) 35–40.

[33] Alexandru Sonoc and Jack Jeswieta,Vi Kie Soo, *Opportunities to Improve Recycling of Automotive Lithium Ion Batteries*. Procedia CIRP 29 (2015) 752 – 757.

[34] Ghassan Zubia, Rodolfo Dufo-López, Monica Carvalho, Guzay Pasaoglu, *The lithium-ion battery: State of the art and future perspectives*. Renewable and Sustainable Energy Reviews 89 (2018) 292–308.

[35] Linda Gaines, *Lithium-ion battery recycling processes: Research towards a sustainable course*. Susmat (2018), doi:10.1016/j.susmat.2018.e00068.

[36] Bin Huang, Zhefei Pan, Xiangyu Su, Liang An, *Recycling of lithium-ion batteries: Recent advances and perspectives*. Power Sources 399 (2018) 274–286.

[37] Liu Yun, Duy Linh, Li Shui, Xiongbin Peng, Akhil Garga, My Loan Phung LE, Saeed Asghari, Jayne Sandoval, *Metallurgical and mechanical methods for recycling of lithium-ion battery pack for electric vehicles*. Resources, Conservation & Recycling 136 (2018) 198–208.

[38] Saskia Ziemanna, Daniel B. Müller, Liselotte Schebek, Marcel Weil, *Modeling the potential impact of lithium recycling from EV batteries on lithium demand: A dynamic MFA approach*. Resources, Conservation & Recycling 133 (2018) 76–85.

[39] Lluc Canals Casalsa, B. Amante García, Camille Canal, *Second life batteries lifespan: Rest of useful life and environmental analysis*. Journal of Environmental Management 232 (2019) 354–363.

[40] S. Rohra, S. Müller, M. Baumann, M. Kerler, F. Ebert, D. Kadena, M. Lienkamp, *Quantifying Uncertainties in Reusing Lithium-Ion Batteries from Electric Vehicles*. Procedia Manufacturing 8 (2017) 603 – 610.

[41] Zhiyu Huang, Zhilong Xie, Caizhi Zhanga,, Siew Hwa Chan, Jaros ław Milewski, Yi Xie, Yalian Yanga, Xiaosong Hu, *Modeling and multi-objective optimization of a stand-alone PV-hydrogenretired EV battery hybrid energy system*. Energy Conversion and Management 181 (2019) 80–92.

[42] Mattia Barbero, Lluc Canals Casals, Cristina Corchero, *Reused second life batteries for aggregated demand response services*. Journal of Cleaner Production (2018), doi:10.1016/j.jclepro.2018.12.005.