TRIZ Directed Evolution for Automobile Fuel

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Abstract. Recently, Global Warming effect and Green House Gases (GHG) emissions have become one of the main concern for environment that principally come from the exhaust of fossil fuel combustion process (i.e. coal, crude oil, and natural gas). Electric Vehicles (EVs) industry has started taking the lead and showing significant competition in the market via Plug-in Hybrid Electric Vehicle (PHEV) and fully Battery Electric Vehicle (BEV) over the conventional fossil fuel powered vehicles which are going to ban (prohibit) within coming two decades as officially announced by many of global countries. Battery is the backbone of this evolution and it encourages many researchers and scientists to expedite their studies, experimental tests to discover the best reliable, sustainable, and safe resource of energy to meet the customers' (vehicles users) values, satisfactions and expectations. This study aims to scientifically predict and analyze the future battery generation that last longer up to (500 km) with improved charging time (less than 30 min). A systematic evolution method called TRIZ (Theory of Inventive Problem Solving) was used in this paper to link the historical data with present timeline in order to improve the main characteristics of the battery (e.g. energy density, durability, charging time and safety). TRIZ has variety of inventive tools (9 –Windows, S – Curve and Function Analysis), these tools are efficiently assist to predict and achieve the next generation of the future battery. By using the tools of Directed Evolution (DE) and utilizing Level of Innovation Domains, battery development is going to be deeply illustrated. Finally, logical recommendations were proposed to those personnel in charge to move forward to approach the future battery system with targeted features and characteristics.

Keywords: Battery Management System (BMS), Directed Evolution, Greenhouse Gases (GHG), Theory of Inventive Problem Solving (TRIZ).

1 Introduction

Practically, fossil fuels as coal, crude oil and natural gas were formed anciently and nowadays they perform an essential influence in humankind's global evolution. Unfortunately, the burning fossil fuel releases toxic gases which in turns make a contribution to acid rain and global warming effect. However, the main source of automobiles energy is "Fossil Fuel" and the total oil production reached a peak during this century. Recently, the recent assessments, environmental associations' policies, and restrictions show that petroleum-based fuels is going to be prohibited by the year 2042. The engine's fuel evolution has grown up rapidly and has obviously followed the behaviour of matter status as Solid (coal), Liquid (petrol/diesel), Gas (NG) and Field (electrical). Batteries industry and its high technologies have been significantly improving. Since early 1990's, Lithium battery's technology has taken the lead of the era of electronic devices evolution (e.g. cell phones, laptops, and smart watches) as well as the automobile industry [1][2].

2 Evolution of Technologies

2.1 Fuel Evolution of Vehicles' Engine

Engine is the key part of vehicle and simply considered as the heart of automobile and even functioning likewise. In general conventional sense, engine converts the chemical energy in fuel (petrol, diesel and NG) into mechanical energy of moving a vehicle forward. The engine's fuel evolution has grew up rapidly and has obviously followed the behaviour of matter status as Solid (coal), Liquid (petrol/diesel), Gas (NG) and Field (electrical) [3]-[6].

2.2 *Batteries at Electric Vehicles*

A battery is a generator of electrons via electro-chemical reactions, it has positive (+) and negative (-) terminals. The early battery was launched in 1859 by lead-acid battery, and then the advanced batteries have been introduced to market with better performance, more efficiency, environmentally safe and even cheaper. At the beginning of this century, batteries was utilized for EV's industry with Lead-acid battery. After that, other technologies joint the market such as Nickel-Metal Hydride (Ni-MH), Fuel Cell, Super-capacitor and Lithium-ion batteries [7]-[10] as shown in Fig. 1.

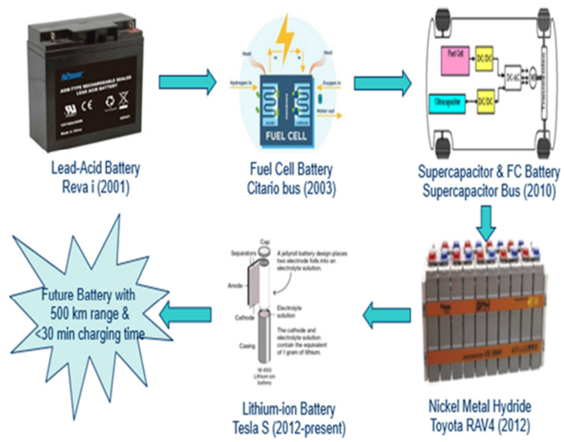

Fig. 1. Batteries at Electric Vehicles Evolution

2.3 Electric Vehicles Classifications

The EV's present a good successor of existing petroleum automobile for many reasons, the key words that show societies prefer EVs comparing to conventional vehicles are the No-gas emission and less noise pollution. Due to air pollution and gas emission laws, the automobile producers were requested to produce vehicles with matching emission specifications which in turns lead to significant improvement of the electric vehicle industries. EV's have three categories based on the engine vs. battery installation as well as its charging technology [11]; these three categories are Hybrid Electric Vehicle (HEV), Plug-in Hybrid Electric Vehicle (PHEV) and Battery Electric Vehicles (BEV).

3 Directed Evolution Method

3.1 TRIZ Method

TRIZ is a Russian phrase "Teorija Rezhenija Izobretatelskih Zadach", that means "Theory of Inventive Problem Solving". It is demonstrated systematic method to solve problems. It was developed when the scientist and engineer Genrikh Altshuller reviewed thousands of patents in 1946. He revealed that a technical system evolution of is not a randomly occurs but overseen by guaranteed objective rules [12][13]. TRIZ has valuable and significant tools that have different features to support the scientific prediction of the future generation, which include 40 inventive principle, Contradiction Matrix, 9-Windows, S-Curve and Function Analysis.

3.2 Directed Evolution Method

The Directed Evolution (DE) is a proactive technique that utilized by an organization assigned for the development of new system, products, processes, services and technology. It is the preparation of an inclusive scenarios that helps for future planning and current development to achieve the proper successor [14], [15]. five stages of DE are shown in Fig. 2.

1. Collection of historical data
2. Directed evolution diagnostics.
3. Synthesis of ideas
4. Decision making
5. Supporting the process evolution

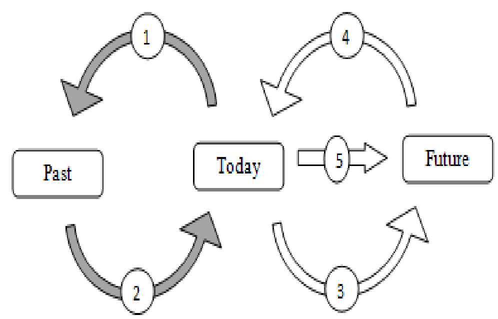

Fig. 2. Stages of Directed Evolution

4 Result and Discussion

4.1 Collection of Historical Data

Lithium-ion batteries (LIB), is one of the most familiar rechargeable sources of energy, it has led in portable electronic items in markets for last 25 years. Nevertheless, the existing technology of LIBs which just about reach the theoretical capacity and leave little competition space for further assessment which is not able to hold the current applications requirements (e.g. Electric Vehicles) that need more capacity and better lifecycle. With huge demand and massive market prospective, re-chargeable source of energy with greater density and lower cost remain crucially under investigation [16]-[19].

Table 1 shows the relationship of battery technology among Past-Present-Future stages and taking in consideration the influence of internal and external factors.
In the past, a Lead Acid rechargeable battery with basic internal (sub-system) component (e.g. anode, cathode, liquid electrolyte and wiring connection), while external components (super-system) were limited to safety and raw material concerns.
In present, Lithium-ion technology is improved and its “Battery Pack” version has taken the lead in automobiles industry via its additional (sub-system) components (e.g. different substances of and cathode, solid electrolyte, separator and battery modules). Its related (super-system) components encourage the process development (e.g. charging stations policies and local authority).
In the future, the new vision of battery technology is going to be enhanced components. The researches for sub-system components help to predict the next generation technology with hybrid anode and cathode using more effective substances (e.g. Sn-Li, Sn-Na), solid electrolyte, CAN communcation system, new flat shape and rack mounting design, installing smart monitoring sensors).

Table 1 : TRIZ 9-Windows for Battery Technology

	Past	Present	Future
Super-system	- RoHS Standards - Battery Supplier	- RoHS Standards - Battery Supplier - Charging Station - Local Authority	- RoHS Standards - Battery Supplier - Charging Station - Local Authority - Replacement System - BMS
System	Rechargeable Battery (Lead Acid) (LIQUID)	Lithium-ion (Li-ion) Battery (FIELD – Single material)	Battery of 500 km capacity range and less than 30 min charging time (FIELD – Hybrid)
Sub-system	- Anode (Lead) - Cathode (lead-dioxide) - Electrolyte (Sulphuric acid) - Wiring Connection	- Anode (Graphite, LTO) - Cathode (Li, Al, Ni, Co) - Electrolyte (Solid) - Quick Connection - Separator (polyethylene) - Battery Modules	- Anode (Sn-Li, Sn-Na Hybrid) - Cathode (Li, NCA, S) - Electrolyte (Solid) - Separator (Tin, polymer) - Rack Mounting - Flat Shape - Monitoring Sensors

4.2 Directed Evolution Diagnostics

As the main step of this strategy, the diagnostic stage needs more concentration, brainstorming and connection of all collected data that were got about the history of battery, competitors, advantages & disadvantages, etc. By applying a dedicated knowledge of 9-windows and data collection, S-curve analysis can help to identify how the correct directions for future development to achieve the targeted specifications as shown in Fig. 3.

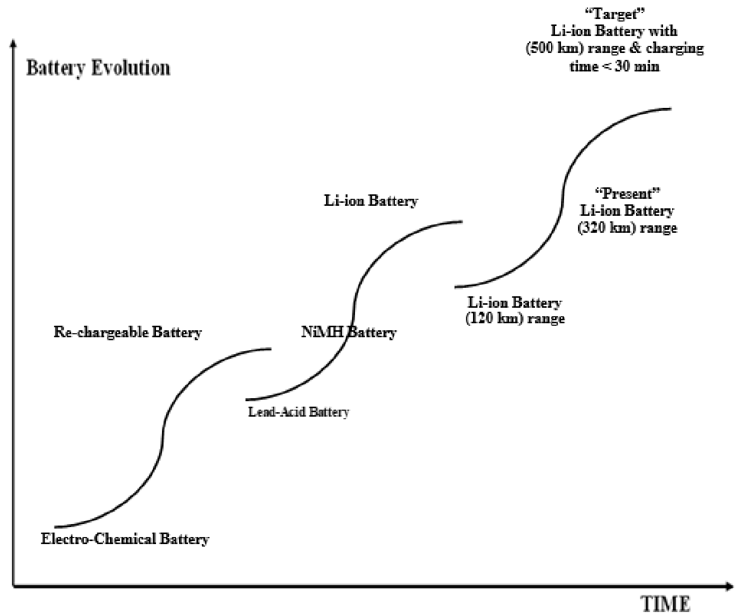

Fig. 3. Lithium Battery Prediction S-curve

4.3 Synthesis of Ideas

This stage aims to create ideas which will transfer the recommended battery to the next step of evolution. Tools and techniques to be utilized are Ideation brainstorming and Evolutionary Analysis.

Based on 40 inventive principles, some principles have been useful in generating the idea of future battery.

For Principle 3 (Local Quality), changing the structure of the battery is one of the improvement modifications and the flat shape of the future battery is going to have many advantages for utilizing efficiently the maximum available size and even to save more space on the vehicle.

For Principle 8 (Anti-weight), the new rack mounting design will decrease significantly the weight of the battery system which in turn will save more money of the vehicles price.

For Principle 10 (Preliminary action), easy and immediate battery switching feature by providing the vehicle with a redundant battery system (one in duty & one standby). This technique will increase the available energy density (distance range) and dragging the charging time to zero.

For Principle 12 (Remove Tension), changing the operating conditions by changing to new substances and hybrid electrodes (e.g. Tin-Sn and sodium-Na) more effective substances with better performance characteristics, current limitations and even cheaper of commercial materials.

For Principles 13 (The other way round), this principle gives a hint to the manufacturers to utilize the reverse concept of charging/discharging. Battery is moving the vehicle during discharging phase, so why not to be recharged using the rotational movement of the vehicle itself.

For Principle 28 (Mechanics substitution), installing the future battery with smart sensors and replacing the conventional wiring connection of the battery by CAN (Controller Area Network) communication system which provides monitoring, controlling and protection features for the battery system.

For Principle 31(Porous materials), it is one of the important principles and adding a catalytic element such as Graphene is going to improve the charging time due to its superior physical, chemical and mechanical properties.

For Principle 35 (Parameter change)
, changing the structure of the future battery to be more flexible will have positive impact on physical (less weight), technical (less effected by external environmental conditions) and even safety characteristics (no leak or vibration).

4.4 Decision Making

Since this stage needs personnel in sale, marketing, procurement and finance to be involved, so we are not going deeply and will just utilize the questionnaire analysis tool to recommend the needful to those in charge personnel.

As part of marketing and providing redundant battery, many customers have no objection to pay a reasonable amount of deposit while having a quick battery replacement and negligible recharging time.

4.5 Supporting the process evolution

It is not enough to have good plans, there will always be unexpected deviations and out of control issues. Therefore, the earliest four stages can generally be done in a fairly short time. Certainly, they are a preparation for this critical stage of supporting the process, which comprises the process continuous monitoring and making proper corrections if needed. The next concerns need be monitored during the system's development:

- Looking for potential abnormalities in the charging stations environment.
- Predicting deviations analyzing planned versus actual results
- Correction of scenario.

Tools and techniques to be utilized:

- System training to assigned team.
- Continuous data collection of customers' feedback and suggestions.
- Installing battery management system (BMS) including:

Data acquisition, Safety protection, Battery charging/ discharging Controlling, Cell balancing, Showing battery status and certification at the user interface, extending the battery life (charging and discharging cycles).

5. Conclusions

The battery industry is one of the most rapidly improved recently and many researches have being conducted even at the moment of writing these words. The understanding of the battery structure and its made substances will lead effectively to the right improvement directions and create a new generation of battery that has significant features and characteristics such as energy density (Capacity), durability, charging time and safety.

Based on TRIZ inventive tools and Directed Evolution (DE) process, the dedicated physical, chemical and mechanical states of the battery can be improved using the 40 Inventive Principles to predict the next generation of battery system which is expected to have some (or even all) of the following characteristics:

Structure: It has two effected parts,
- Adding catalytic element such as Graphene.
- Using new substances and Hybrid electrodes (e.g. Tin-Sn and sodium Na)

Design: It has three effected parts,
- New flat and flexible shape.
- Changing the state of electrolyte to solid.
- New rack mounting installation.

Charging System: It has two effected parts,
- Including redundant battery system.
- Utilizing the vehicle's rotary motion to for recharging.

Control Technology: It has two effected parts,
- Changing to CAN communication connection.
- Installing smart sensors for monitoring and protection.

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