CHAPTER 1

INTRODUCTION

This Chapter describes the various types of storage systems available and it has been classified with various parameters. It also gives overview of the research work including its significance. Various Storage Systems available are also compared here. The chapter gives the scope of the research work.

Through various methods, human has started storage of energy. It is the worth to have energy storage on the basis of time and capacity. The storage of energy is depended on the availability of the energy, energy consumption time, energy storage time and the location of energy usage to energy storage. Energy storage systems have been helpful in many demands of the society. Various energy storage systems are available in the worldwide. They come into existence based on the area, need of storing the energy and its capacity. They have been clubbed to compare the economical and other parameters. Three categories have been commonly known by researachers: devices with large power and energy storage capacity i.e. Large Capacity Storage System (LCSS); devices with medium power and energy storage capacity i.e. Medium Capacity Storage System (MCSS); devices with small power and energy storage capacity i.e. Small Capacity Storage System (SCSS);

1.1 CLASSIFICATIONS OF STORAGE SYSTEMS:

On the basis of working principle of the storage systems, they are classified as follows:

1. Pumped Hydroelectric Energy Storage (PHES),
2. Underground Pumped Hydroelectric Energy Storage (UPHES),
3. Compressed Air Energy Storage (CAES),
4. Battery Energy Storage (BES),
5. Flow Battery Energy Storage (FBES),
6. Flywheel Energy Storage (FES),
7. Supercapacitor Energy Storage (SCES),
8. Superconducting Magnetic Energy Storage (SMES),
9. Hydrogen Energy Storage System (HESS), and
10. Thermal Energy Storage (TES),

1.1.1 Large Capacity Storage System

The only devices identified with capacity power having more than 50 MWatt and Energy Capacity of greater than 100 MWh are said to be Large Capacity Storage Systems(LCSS). PHES, UPHES and CAES fall under this classification. The potential for PHES is mainly proportional to the suitable sites like all other LCSS. It is experimentally observed that there is hardly any suitable site in the world is left for PHES. PHES is limited by economical as well as time investment, directing that it may grow as the only important storage system as fuel is continuously becoming costlier. UPHES also works on the same principle of the PHES; hence UPHES can become a competitor to PHES. The site for UPHES is rather independent on locations in hilly sites like PHES, which could be meritorious as it is always not possible to create such a huge construction but in only remote and isolated land. On the other hand, only constrain to UPHES site is it requires a suitable underground reservoir. Still today to find such reservoirs a long term survey and exploration with highly technical people are required, thus the future of UPHES remains unpredictable. Finally, the LCSS choice comes to CAES and its attractiveness relies on the cost and amount of gas available with transportation as well as the potential for locations. As long as 30 years are required to identify and construct the structure for the CAES, which is going to be of long life investment and commitment for storage. Though it is reliable, and efficient storage system, it has constraint of large amount of gas requirement. Therefore, if the energy system considering CAES has long term ambitions to eliminate a dependence on gas, due to price, security of supply, etc., then this should be accounted for when analyzing the feasibility of CAES. Eventually, like PHES and UPHES, the potential for CAES also depends largely on the availability of suitable land and specific locations. It is obvious that LCSS facilities all share one key issue: "Specific Location". However, suitable sites for PHES may be more well-known than formerly projected. However, one other main deliberation is the maturity of the verities of technologies [1-4]. UPHES and CAES needs vessels are still only concepts and thus still to be proven. CAES using underground reservoirs is often considered an acceptable storage system as there are two facilities operating worldwide [5]. Based on the location naturally available and capacity of storage per economical investment of PHES, it is the most feasible LCSS.

1.1.2 Medium Capacity Storage System

Medium Capacity Storage System (MCSS) deals from 10 MWatt to 50 MWatt power capacity and 25MWh to 100 MWh capacity of energy storage. BES and FBES come under this category. The only major competitor from the BES storage technologies for future large-scale projects is the NaS battery. LA and NiCd are used for their various private and public existing applications, but further breakthroughs are dubious. FBES technologies (VR, PSB and ZnBr) are all presently struggling in the distributed generation scenario. Demonstration of performance and its success in near future will be decisive for its future. It is worth noting that flow batteries are much more complex than conventional batteries. Compare to conventional batteries, flow batteries are more flexible, though former is constrained, later is complex. With additional parts to conventional batteries, flow batteries can be made an independent storage system for power and energy capacity. The industries of such MCSS likely to grow in near future due to necessity of energy storage from renewable as they are at various locations like solar and winds in Asian Markets. It has also major role in Electric Vehicle performance. If such progress continues for a decade within electric vehicles researches, then battery energy storage system definitely alter the distributed batteries in EVs. [6-8]

1.1.3 Small Capacity Storage System

Small Capacity Storage System has been acceptable since many years but it is applicable to only specific applications. FES, SCES and SMES are under this classification. They basically differ in terms of the power capacity as their energy storage abilities are usually less than 1 hour. Whenever power requirement is below 750 kW, FES is selected. Power demand between 750 kW and 1 MW, SCES is selected, but for large power issues of above 1 MW but less than 10 MW, SMES is preferred. Due to this specific ratio of their energy storage capacities, these technologies are likely to be used for their unique purposes and auxiliary services. However, they are utilized as a main technology for the storage to achieve the society need from distributed energy generation and its integration. [9]

1.1.4 Overall comparison of energy storage technologies

It is quite tough to compare this three clubbed energy storage systems one another since every technology is not perfect for utilization of each and every place. They are individually ideal for specific usage. Accordingly, a number of examples are surveyed and observed the capacity of each energy storage technology in relation to one another keeping various parameters in mind like output energy density, lifespan, power rating and efficiency etc.(Fig. 1-1 to Fig. 1-5).

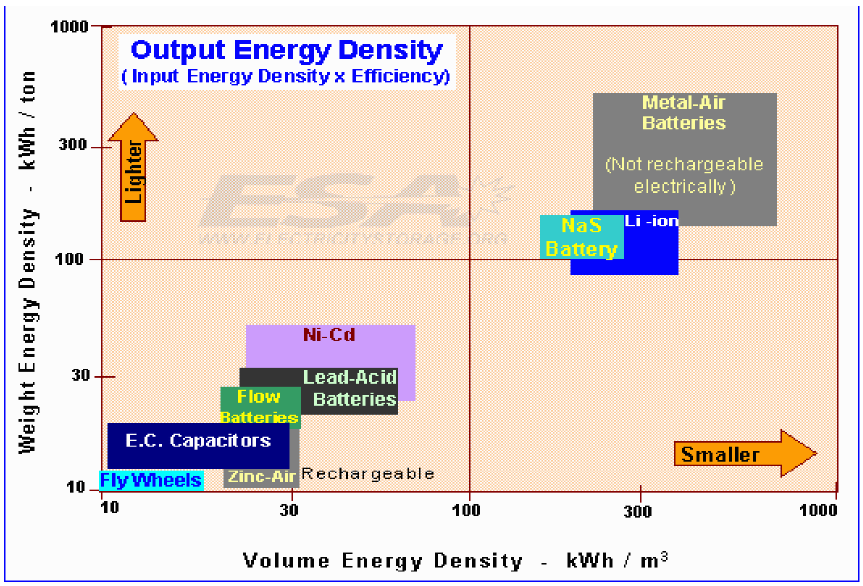

Fig. 1.1 Weight Energy Density vs. Volume Energy Density for each technology [9]

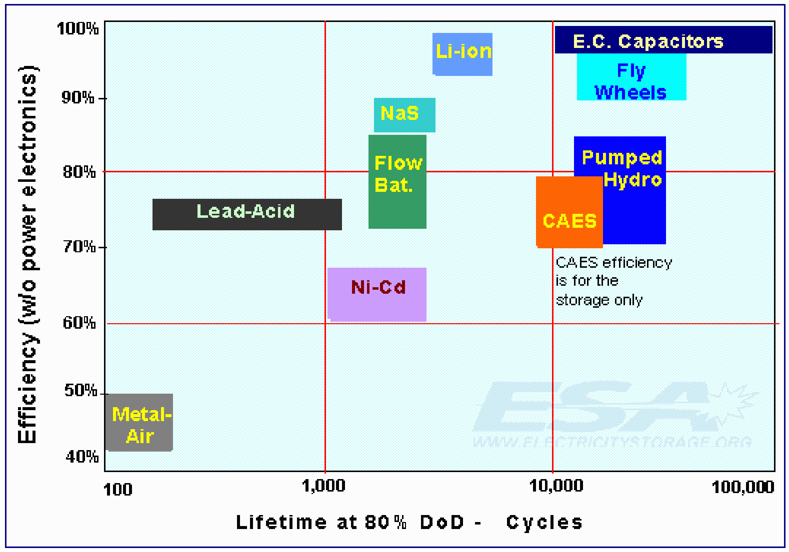

Fig. 1.2 Efficiency & Lifetime at 80% DoD for each technology [9]

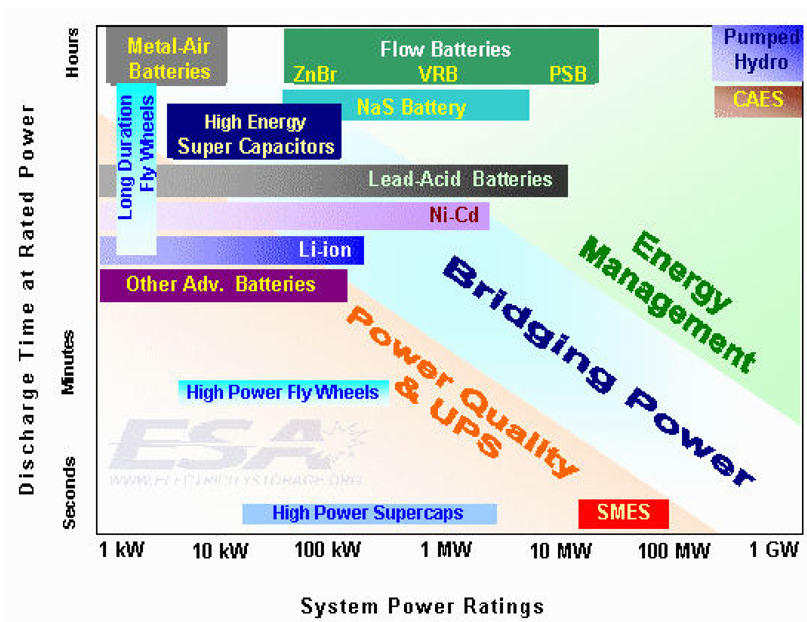

Fig. 1.3 Discharge Time vs. Power Ratings for each storage technology [9]

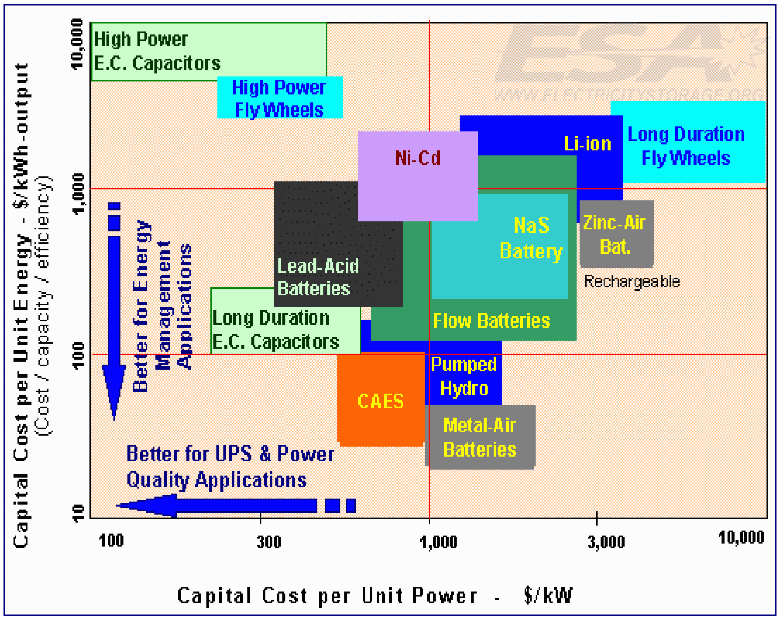

Fig. 1.4 Capital Cost for each technology [9]

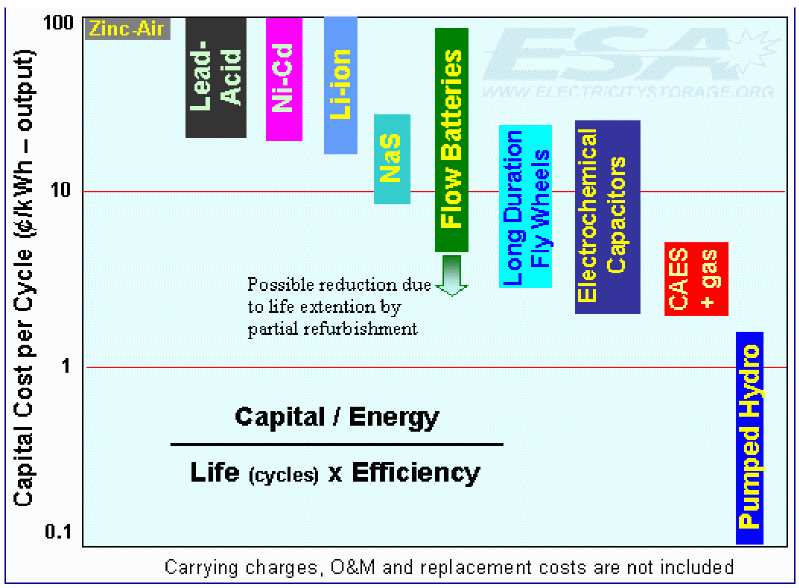

Fig. 1.5 Cost per cycle for each technology [9]

1.2. SIGNIFICANCE OF THE RESEARCH:

The primary design tribulations in Electric Vehicles (EVs) having various energy storage systems, deceit in management of the net energy outflow, purpose of the proportional power divide and concern of methods to crossing point between the energy systems to meet the load of the vehicle propulsion and supplementary weight profiles. The collective procedure of multiple energy storage systems in a methodical collection permits key attributes of the personage systems to be oppressed. However, these energy storage systems require an intercession of their power allocation between the multiple energy storages and the load. This report explains about the power and energy management problem in an organized manner by adopting a new angle and a functional performance of framework. This introduces the practical research of power and energy management in EVs.

1.3. MOTIVATION:

This research is motivated by the argument that EVs represent an economically and technically reasonable option for future transportation systems. Ecological problems, increasing prices of petroleum fuels, toxic gas emission margins and the exhaustion of natural resources provides convincing momentum towards the progress of more ecological solutions. To reduce hazards of gas emissions, creativity with ease in electric vehicular technologies highly depends to the concept of sustainable improvement. The eventually generated challenges require in depth research in many domains. One of such area is advancements in storage system of electric vehicle technology [10].

EVs have been part of life ever since the automobile industries came into existence. However, in the early competition for supremacy, the internal combustion engine (ICE) hastily overtook the EV as the most important propulsion power system for vehicles. Although the electric power train was better in terms of operation and energy conversion efficiency, the preventive reason remained the source of electrical energy and its transportation. Battery motorized vehicles plainly could not match the high-energy density, plentiful supply and financial attributes of petroleum based propulsion. Even with ICE energy conversion efficiency figures of below 20%

[11, 12], the energy density (Joules/kg) of petroleum extremely surpasses the energy density of any recognized battery technology. The ICE is progressively more becoming a target of ecological debates. Assuming that private transportation continues to be a fundamental link in the economic chain of current societies, private automobile appears to be the system of choice. This would give opportunities to reorganize private transportation system as it is now. At present, EVs have obtained eventually a strong global attention, after more than a century since its innovation. The feasibility of a purely electric vehicle as a future transportation solution is perhaps questionable. The single limitation of current EVs compared to an ICE Hybrid EV is still the travel range. Modern society has started adapting the ecological solutions and hence EVs and HEVs are better options. As a near expectation, EVs will find explicit applications where short travelling distances or predefined routes state the vehicles' comfort & range requirement.

1.4. THE EMERGING AREA OF ELECTRICAL VEHICLE & ITS RESEARCH AREA:

As the research of electric and hybrid EVs is becoming quite promising, improvement in not only propulsion systems but also in energy storage units has taken significantly worldwide attention. In the course of vehicles becoming "More Electric", with increasing number of onboard electrically powered subsystems for both public and private needs of transportations, the expectation to manage energy in the vehicular power system is necessary. Electrical power management for both traction and auxiliary needs are expected to increase as the automotive power system shifts towards largely on the electronics based environment [13-15]. The demand of the EVs has been varied due to its specific need from the industries as well as individual profile. But, this complex demand profiles predictable by these dynamic loads require perfect and optimized control of power management and energy flow from storage subsystems within the vehicle thus creates an intelligent technical problem and occasion for vehicular power and energy management & control research. The term "Electric Vehicle" can be understood that any vehicle with an electrical energy source and its propulsion system. This should include road, rail, water and air vehicles but in fact it has become commonly acknowledged by both the society and industrial community that "EVs" are referenced utterly to road vehicles only. [16, 21].

Under the term "Electric Vehicle" (EV), various names exist based on source of energy and emissions as below:

1. Hybrid Electric Vehicle (HEV),
2. Fuel Cell Electric Vehicle (FCEV),
3. Battery Electric Vehicle (BEV)
4. Zero Emission Vehicles (ZEV)
5. Ultra Low Emission Vehicles (ULEV),

In an EV, the energy resources are quite restricted. However it is essential that the power demands from all loads to be satisfied. On the contrary, with the limitation in energy systems, it is unrealistic and unaffordable to size a single energy storage unit to supply continuous power requirement many times more than the average power requirement, just to achieve transitory peaks in power needs. For this cause, employing various on vehicle energy systems that are specialized for the verities of segments within a vehicular power & energy demand range becomes a practical way out. The combination of energy storage devices with high energy density (Batteries) high power density (Supercapacitors) provides such an important solution. The task of a power and energy management system then is to suitably coordinate the dynamics of the energy storage systems. This is to be done without compromising the vehicle target performance. Energy storage systems on EVs can be categorized as either charge sustaining or charge depleting. The latter refers to a system with a curtaining state of charge (SoC) as the vehicle performs, thus restraining to its operational boundaries. In such systems, power and energy management is even more important as it contributes to widen the operation boundaries. The term Electric Vehicle (EV) suggests that it shall be a vehicle with at least one charge depleting energy storage system and an electric propulsion system in a drive train configuration. Fig.1.6 gives idea for the power train layout of a series EV.

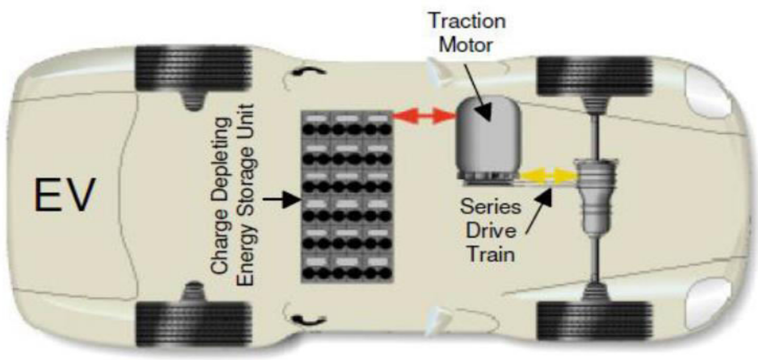

Fig.1. 6 Power Train Structure of EV

There are multiple reasons to increase the curiosity in the research of EVs. One of the reasons is due to the increasing consciousness of society for ecological issues and its effect on human health. A technical cause can be to the initiation of new technology availability such as efficient fuel cells, electrochemical double layer capacitors (EDLC) and large-speed compound flywheels. For a long period, it was a widely excepted fact that EVs were limited to applications due to the intrinsic power and energy density limits of battery technology [14, 16]. The progress in the chemical technology and power electronics inventions have created new scope for the research activities in EV. From evidence of scientific and industrial efforts, government backing and present technology, EVs have a major viewpoint of entering into the society and maintaining its existence this time around. However, the acceptance rate in terms of public opinion will basically depend on three factors. The EVs' easy operation without maintenance, larger running average (cheaper) and the exhaustion of natural resources will leave suddenly no other choice to the society but only EVs.

1.5. RESEARCH SCOPE:

The automobile industry for EVs is currently going through a revolution period with the introduction of multiple voltage systems to meet future electrical load requirements. As such, research offerings towards this field are appropriate. Efficiency of electric vehicle energy storage systems is a basically research-level problem. Every characteristic of the system has an effect on the energy management its outcome, and the impact of a given energy system is generally dependent on it's interlinks with other energy systems. The target of a structured power and energy management system for battery/supercapacitor powered EVs is to meet the efficiency expectations of the vehicle user and to minimize the loses such that it optimizes the overall system efficiency while the charge levels of the energy sources are depleting. This energy source integration has to be done with an objective of shrinking the total weight and price of the vehicle. Little work in energy management in the past has tried on addressing energy savings options for portable battery operated devices. "Energy-aware" program while on vehicle and power saving performance characteristics have been quite successful in these user friendly devices. It would definitely show that power management in electric vehicle technology is purely a measured execution of the techniques used in organizing power & energy in these devices. This could be accomplished by basically switching on and off the energy systems after a predefined timeout. In the perspective of an electric vehicular application, the power and energy management question addresses more than just supporting the energy levels [13 - 16]. It includes the harmonization of energy system, power flow, managing various energy storage systems and also confirming power saving and stability.

An important advantage of EVs is the suitable system for recapturing energy lost during regenerative braking. This primarily differentiates the power and energy management requirement of an EV to other mobile battery powered equipment. The challenging task is to capturing the regenerative energy which is actually lost and storing it back into the onboard energy storage device. High power flows during rapid decelerations makes an open challenge for the energy storage system to be adoptive in case of returning currents to the energy storage system. On the other hand, during accelerations, high power is to be satisfied from the energy source. Though, the internal properties of batteries intervenes rapid charging or discharging without critical temperature rise, which consequently leads to reduction in life and early failures. To rectify battery high power stresses, an intermediate power storage or peak power storage is expected by technology innovators. With today's technology, the "Supercapacitor" is a representing the alternative for the said expectation and it is an electrical peak power device too. The challenge now is the hybridization of batteries and supercapacitors within the electric vehicle power systems structure. To what degree the incorporation of these two energy storage systems can be oppressed is of considerable exploring interest. In consequence of this expectation of a multiple energy sources, power and energy management of EVs presents an even more demanding task. It expects firstly the development of a higher-level control scheme that estimates the comparative amount of power to be generated, and divide it between the two energy systems. These sources are configured electrically within the vehicle power system and the power flow and energy systems are coordinated is a power electronics intensive problem requiring a systems level supervisory control scheme [23, 24]. Research for various methods for electric vehicle power systems management which results into the use of batteries and supercapacitors in synergistic operation is still not well established.

Conversely, a growing community of enthusiastic researchers is actively exploring towards the aim of achieving fundamental concepts for vehicular power & energy management so that it can get efficient electric vehicle power system. Areas that are presently extent of research in an EV [19, 20, 22]:

► Rating of onboard charge sustaining and depleting energy storage systems.

► Harnessing the regenerative energy.

► Supplying peak power using storage units.

► Harmonization of two or more energy sources of diverse power/energy specifications.

1.6. PROBLEM SCOPE:

In the scope of this research, the design of the hybrid storage system which has both supercapacitor and batteries is as follows:

► The method of power flow between batteries and supercapacitors

► The peak power blending infrastructure for supercapacitor system.

► The energy flow with usage of vehicle propulsion system.

► The analysis of regenerative energy in vehicles.

► The decision time for the storage of peak power into supercapacitor system.

► The presentation and analysis of theoretical and practical findings

The driveline architecture that is designed and supervised includes the two energy storage systems categorized as Type 1(Battery) and Type 2 (Supercapacitor). As depicted in Fig. 1.7, the research includes the power conversion and its control along with power and energy management between Type 1 and Type 2 systems. The vehicle load demand that is analyzed is limited to the propulsion loads and type of vehicle.

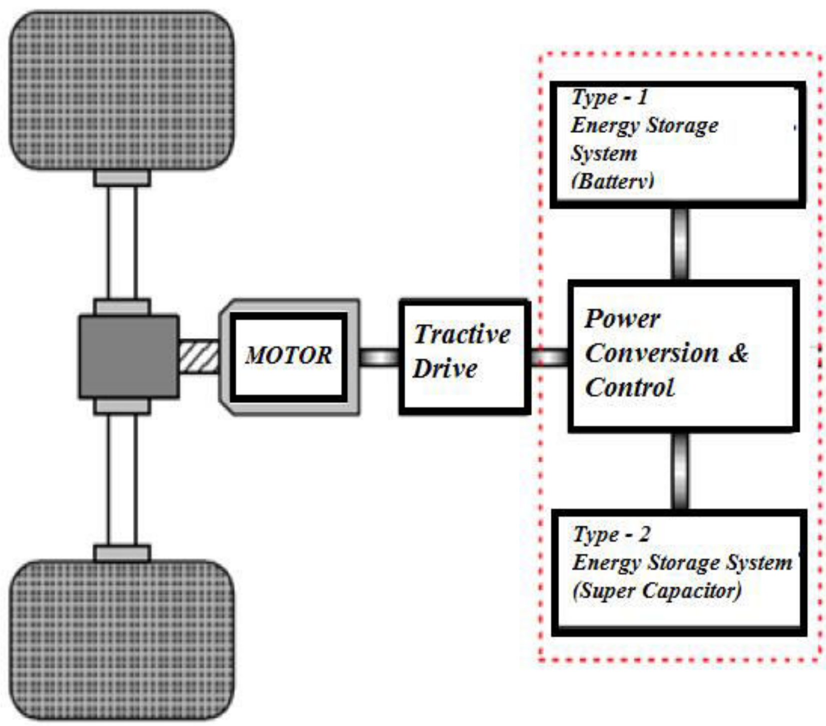

Fig.1. 7 Power & Energy Management System