BARRIERS TO ADOPTING THE SUPER-CAPACITOR BASED ENERGY STORAGE SYSTEM OF ELECTRIC VEHICLES IN PAKISTAN

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ABSTRACT

The super-capacitor is becoming one of the potential tools for storing electrical energy for the upcoming models of Evs. As the population increasing the demand for non-renewable resources could not be enough, also the carbon based Vehicles producing harmful emission that is negatively impact our environment. Looking at these two major issues making super capacitor is a more favorable option for storing electricity of Evs. These devices have earned their significance in numerous applications, viz., to power hybrid electric/electric vehicles and other power and electronic systems which require electrical energy for their operation. The dominant quality of super-capacitors is that it is a product of eco-friendly and harm-free energy storage device that provide high energy power and long life as compared with other energy storage. But to adopt this technology in Pakistan is not an easy task, there are many barriers come into existence because majority of the Vehicles are fuel based. In this research we will deal with the major barriers that threaten the initiative toward adopting super-capacitor technology especially in vehicles. Strong customer base for Gasoline vehicles, Shortage of Electricity, lack of proper policy, lack of awareness, need of high cost infrastructure development, high price of super-capacitor Evs, limited range are major issues for Automobile industry to take steps for Super-capacitor technology.

Keywords: Electrical Energy Storage System, Energy Storage Device, Electric Vehicles, Super-Capacitor Technology, Consumer Response, Non-Renewable Resources, Automobile Industry of Pakistan, Filling Stations, Electric vs Traditional Vehicles, Super-Capacitors.

INTRODUCTION

The world to come will definitely go toward better condition, as today our main concern is for how to protect environment, save non-renewable resources and produce emission-free energy and electrical products. Day by day the level of non- renewable resources is reducing, and one day they will be empty. So to address these problems, we are focusing on generation of renewable and clean energy resources for our future. In these initiatives the Automobile industries also playing their main role, because the main reason of pollution and greenhouse

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gases is transportation that emits around 14% greenhouse gases globally and it ratio will double by 2030(He et al. 2019).The conventional vehicles are designed with internal combustion engine that run on fossil fuels like petroleum and CNG. The internal combustion engine emits highly harmful gases and the cost of fuel is also high in many countries. In 1898, the very first time Dr. Ferdinand Porsche come with solution of these issues, he introduced the hybrid electrical vehicle (Vukajlović et al., 2020).

The Electric Vehicles is the updated version of vehicle and as its name suggest, it the vehicle that run on electricity (electric power). The electric Vehicles (EVs) are now becoming the concern for every transportation industry as well as for the general public. It is emerging as the green product with the identification (facility) of zero-emission and ecofriendly vehicles (Massiani, 2015). Now let's take a closer look inside the electric vehicles that have some special component then rest of the type of vehicle systems. So instead of internal combustion engine in traditional vehicles the electric vehicles have an electric motor. And as like every other electric motor this motor also needs continues power and that power provider are the traction of battery packs that are rechargeable. Other than electric traction motor and traction battery pack or capacitors, the electric vehicles have some other prominent components like charging port, Dc converter, on-border charger, power electric controller, high voltage electric cable, thermal system, transmission and etc. Above all components the electric storage devices (batteries and capacitor) is the very distinguish and important components of electric vehicle (Singh et al., 2019). Now let's dig more know and how about the electrical storage devices of electric vehicle.

The electric storage devices are the devices that used to store energy, it is like the water-tank that storages large amount of water i.e. Energy mainly in two types, one in the form of batteries and other is the capacitors. In the battery the electro-chemical reactions happen with the help of anode and cathode particle charge and discharge to store electricity like in lithium batteries (Wang et al., 2019). And the next is capacitor that work in other way on capacitance conduct and electromagnetic reaction that store potential energy electrostatically Only batteries or only Capacitor is not enough for providing high energy with power density. This limited application of both batteries and capacitor generate the need of advance energy storage devices, here the super-capacitor/ ultra-capacitor and electrochemical came into existence which could replace the traditional battery system (Choi et al., 2014).

Aim and Objectives

The aim of this study is to understand the possible outcome of the impact of implementing the super-capacitor technology in the area of developing countries like Pakistan. Also understand the current challenges in automobile industry of Pakistan. We also use the up to date data to figure out the actual circumstances. We also study different surveys regarding the barriers, challenges and outcome of energy storage devices i.e. super-capacitor and ultra-capacitor. Also the motive behind this study is to help the manufacture, producers, policy maker as well as customers regarding the success changes of super-capacitor technology in Pakistan. Providing the information to the foreign investors to invest in the startup of the super-capacitor technology is also one of the main objectives of this study.

Super-Capacitor

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The super-capacitor is a special and advance type of electrolytic capacitor that has a structure that allows them to store much more charge than any normal electrolytic capacitor. The small super-capacitor cell has 500 farad capacity of storage, and it is estimated that the super-capacitor stores 100 thousand times than the normal capacitor which has around 4700 micro-farad capacity of storage. It provides more current than batteries which could help in high speed acceleration and de-acceleration but with one backdrop is that the low voltage rate (Jayalakshmi & Balasubramanian, 2008). The structure of is based on electrostatics instead of chemical. There are two opposite charge electrodes that are separated by the metal coated plate which is made of powdery charcoal. In this electrostatic process there is no exchange of ions and the gap between these electrodes is very thin that make super-capacitor quicker for charge and discharge. Today the super-capacitor is along used with batteries it can help fast charging electric vehicles. By the example of Tesla Electric Vehicle that normally takes 12 hours to charge full but after using super-capacitor it can charge within 30 minutes. See how much the super-capacitor save our time in this busy world, so it the real future of tomorrow (Kouchachvili et al., 2018a).

The super capacitor energy storage system is our next generation technique that is improving day by day with research by Tesla and Maxwell. In recent time super-capacitor is a sensational topic of discussion, because it is helping in resolving major problems of today such as depletion of energy resources, increasing demand of eco-friendly products. Because it is product of eco-friendly and harm-free energy storage device that make its position in the market of mobile devices such as Cell-phones and electric vehicles (Najib & Erdem, 2019). Basically the super capacitor was introduced before 1990's but that has no commercial use. Like in 1957 the General electric co. introduced the super capacitor first time that are not for any general use, after that standard oil Co. in 1966 that was working on fuel cell unintentionally found the double layer super –capacitor. But in the late 1970s, the first commercial useable super-capacitor developed by Japanese company NEC Corporation (1977) that was used in computer for memory back-up, these all are the innovation of super-capacitor for other devices. Companies like Maxwell, Tesla are really putting efforts in the super-capacitor field, recently the new innovation in super-capacitor like Graphene-based super-capacitor are making their place in electric vehicles (Lv et al., 2020).

Now-a-day in 21st century many countries are trying to adopting the super-capacitor electric vehicles technology. Chariot ultra-electric bus was introduced 7 years back in china. And in April 2018 the china also introduced the first super-capacitor tram with very high efficiency(Wen et al. 2021). Tesla is one of the American Electric Vehicles company also working on super-capacitors like the S70 electric car, the new model that is based on super-capacitor will also release in new future (Yaïci et al. 2019). These are all the innovation of developed countries, but the question arises is that for developing countries that economy is not much as strong as developed countries can be able to adopt this new technology. If specifically talking about Pakistan is under developed country, and it has not their own transport manufacturing industries. Also the energy crisis is at its peak point in Pakistan. So how the super-capacitor technology will be in Pakistan and how it will impact the traditional battery system will the real innovation of super-capacitor. There is around 6-12-hours load shedding occurs in normal days. (Rajper & Albrecht 2020).

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General Scope of this Study

The increasing world population and the technological development have led to an annual growth in global energy demand up to 2% by conventional energy sources in the last 25 years therefore, clean and sustainable energy generation, energy conversion and storage technologies are of prime importance. Super capacitors are devices with unique qualities among energy storage systems.

Super capacitor characteristics include high power densities with relatively high energy densities, fast charge/discharge and long shelf life. Many applications already take advantage of these attributes, for example, large-scale transport systems, i.e. underground trains and buses, power electronics, smart grid applications, energy storage in intermittent generators as wind turbines and photovoltaic cells. Electrode materials are considered one of the most important elements that define the electrochemical performance of the super capacitor.

Various studies report the production of nitrogenized ACs produced by carbonizing 1 3 rich nitrogen precursors or modifying the surface with urea, ammonia and melamine at high temperatures, as well as by nitration reactions. Surface modification with nitric acid (HNO 3) is a typical method to introduce oxygen-surface groups. In addition, this treatment also introduces some amounts of nitrogen functional groups, although most of the research focuses on the incorporation of oxygen-surface groups as carboxylic acids, phenols, lactones, ketones and quinines.

Problem Statement

We all are living in the world full with new innovations and technologies, everything is getting improve day by day, but till our majority transportation system is based of internal combustion engine that run on fossil fuels like petroleum and CNG that emit very dangerous gases like Co2 in our environment (Khan et al., 2019). In this 21st century the electric vehicles are also introduced in the marketplace, but in these vehicles the energy storage devices are still batteries. The main problem in the batteries is taking longer time duration for recharge and also it cannot storage large amount of energy power. Another is the rate of degradation of lithium ion battery is also very high and the heating problems. All of these problems influence to do research about the upper-capacitor technology (Li et al., 2017).

For the developing countries it is important to notice that before using super-capacitor technology, there must be sufficient electric power structure, and also the affordability for common people (Rajper & Albrecht, 2020). But there is a big gap between the needed electricity generation and actual electricity production, it is around 5000MW gap between the actual and needed electricity production Super-capacitor is the new technology but till very expense and in Pakistan the majority is of average income people, so there will be any demand for these type of super-capacitor based electric Vehicles. The high price of E4ws makes it out of range for common or middle class person to purchase. So for test the response of customer to introduce the super-capacitor technology must be on E2ws like motorcycle or bike. Mostly the source of transportation in Pakistan is petrol-based vehicles that consume 57% of total oil resource specially the two-wheeler motorcycle. So if the small changes will make to change petrol-based motorcycles to E2ws, can save the large amount of energy and as well environment by lower emission of harmful gases (Rajper, 2020).

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Every new product or technology face barriers and challenges to enter in the, here we will discuss some of these issue. By this study we will figure out how much this technology will help to reduce the monopoly of petrol prices, dependence on fossil fuel and change the perception of people. Also there is nearly negligible knowledge regarding the impact of super-capacitor technology of electric vehicles on environmental, economic and social condition of Pakistan is present. So overall the problem statement resolves around the will be the impact of super-capacitor technology in Pakistan. The result of this study would help our policy makers, producers as well as consumer to clarifying there doubts about the super-capacitor technology.

Research Questions

By taking all the above scenario in mind, there are some questions arise that need to take consideration in this thesis work.

Q1: Will super-capacitor technology make its position in automobile industry of Pakistan?

Q2: What are the major barriers faced during implementing super-capacitor technology in Pakistan?

Q3: What effect does super-capacitor technology on environment sustainability of urban area of Pakistan?

Q4: What would be the perspective of manufacture regarding super-capacitor technology in electric motorcycle?

Q5: What steps government needs to take to initiative super capacitor based electric vehicle?
We will try to find out answer of these questions in above literature review and discussion

Hypothesis

H_1: *If traditional batteries system changes then environment sustainability increases*

***H_2*:** *E2Ws are favorable for developing countries as compare to E4Ws.*

***H_3*:** *Electricity storage make super capacitor technology less favorable for Pakistan*

***H_4*:** *Increasing growth of automobile industry of Pakistan encourages entrance of Evs.*

***H_0*:** *There is no response of automobile industry toward Evs.*

LITERATURE REVIEW

(Horn et al., 2019) examine the super capacitor as the futuristic source of power in electric vehicles. This study investigates that till 2030 majority of traditional transport change to electric based transport. According to this research in any electric vehicles the cost making part is electrical energy storage system and also it the component that help to reduce emission of harmful gases. There are two goals of this study, first study why the super capacitor is taking place in Evs market and ultimate aim to study the barriers in change batteries to super capacitors. The conclusion of this study is that today the automobile industry trying to reduce the negative environment effect of vehicles that why they are trying to shift the battery system to super-

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capacitor energy storage system. the result also clarifies that the super-capacitor is far better than the batteries in term of charge and discharge, power, quality, lifespan but also super capacitor needs to continues and quick improvement to become future power for electric vehicles.

The option for vehicles are changing from traditional vehicles to electric vehicles, but the most important component in it i.e. the energy storage system still not compatible with fuel based vehicles (Kouchachvili et al., 2018a). The energy storage system should change because the traditional batteries lack in power, charging, and capacity and also the capacitor has low voltage and high cost issue. So the new energy storage device for Evs must be the conclusion of both i.e. hybrid super capacitor electric vehicles. This study also concludes that there are a lot of research is needed to implement such complicated energy storage system in future EVs.

(Rajper & Albrecht 2020) put forward a literature review, their study provide a critical review about the barriers and opportunities to electric vehicles in developing countries. This study is based on the electric data collected from the 2010 to 2016 from different sources like Google scholar and. Day by day environment sustainability become more important success factor so it is important to work on emission free electric vehicles. To change vehicles to Electric vehicles in developing county, sustain electrical power structure and affordability of people is must calculate. This study focus three type of EVs hybrid EVs (rickshaw), 2 wheeler Evs (motorcycle), and 4 wheeler Evs(car). By understanding different perspective, it is estimate that E2Ws and HEV can be the best option to introduce in developing countries because the E4Ws are too expensive to purchase. In the developed countries electric vehicles are common now but in developing countries except china are far back in the race. The motive behind making Electric vehicle more frequently is to save energy, reduction in dangerous gas emission, lower cost for infrastructure and lower down operational cost. But introduce EVs in developing countries is one of the tough task because of electricity storage, high purchasing cost, slow speed of E2Ws, lack of knowledge, poor policy system, and high cost for infrastructure development.so the overall conclusion of this study come out that the E2Ws is favorable for developing countries due to lower purchasing cost with low infrastructure cost.

(Vukajlović et al., 2020) empirically investigate the effect of super capacitor on the lifetime of battery in energy storage system as well as the performance of electric vehicle. Electric vehicle is taking place in the automobile industry but one thing makes EVs less favorable that is the battery based energy storage device. There are some major issues with battery like limited lifetime, harm to environment, less potential of power; these issues with battery develop the need for advance energy storage device like super capacitor or ultra-capacitor that has long life, high power capacity and ecofriendly. The result of this shows that there is positive result come from the use of the super capacitor on performance, durability, and on economy.

Review the new policy for automobile industry of Pakistan for the year 2016-2020. There are some key changes highlight in this policy like the reduce in import barriers to attract foreign investors, ease for new manufacture by giving leniency in taxation, as well as advancement in the quality of vehicle. Day by day countries like USA, China, and Sweden trying to eliminate the fuel based vehicle. Also the Indian government influence automobile manufacture to take step forward for Evs. So there is no doubt that Evs is our future mode of transportation. So there will be Evs in Pakistan as well because Evs are the Global perspective, every country work to shift the transport mode on Evs. Evs in Pakistan need proper set of policy recommendation, so that the actual result can achieve. This ("Electric Vehicles in Pakistan : Policy Recommendations Volume I Cars," n.d.) Study suggests some important policy term to start Evs in Pakistan. The

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policy to reduce the duty and taxes for Evs to 5%, policy for producing sufficient electricity to meet requirement of Charging, the recommendation of next policy is that development of charging infrastructure with reduce tax and duty. The conclusion of this study show some strategy to introducing Evs in Pakistan, these strategies change to size to size of vehicle but the ultimate objective will be achieved.

In many areas or industries specially in automobile industry, super capacitors are becoming one of the best option of storing electrical energy because of their emission free and eco-friendly characteristics (Kamel et al., 2021). The continues research and development bring new opportunities for the advancement in super capacitor technology. (Huang et al., 2019) But there are also some barriers that need to be address. Technical problems, infrastructure cost, establishment of electrical parameter models, policy and industry standards, and consistency of quality are some main barriers that make super capacitor technology less favorable. The end result of this study concludes that these barriers must be addressed, so that the super capacitor technology becomes the future of Evs and other electrical devices.

RESEARCH METHOD

First of all, we collect two different type of data first we collect data regarding the challenges of existing automobile vehicles in Pakistan. And for that the sources of data collection were Pakistan Auto Motive Association (PAMA) and Pakistan association of automotive parts & Accessories Manufacturing. The information about models, duties, tax structure, regulation and new polices and news were studied of about 5 years. In this study we are focus top market share ranking automobile companies i.e. Suzuki, Honda, Toyota, Nissan and Kia. And also specific the data of current challenges facing of above mentioned automobile brand were gathered from their own official website since 2018.

The second research method is design and conduct for the current challenges of super capacitor technology in developing countries. And for that went online search engine mainly Google Scholar, IEEE and Web of Science. There we collect information by using the words, super capacitors, and super-capacitor in developing countries, challenges for super capacitor technology, electrically charging Evs, ultra-capacitor. And also the main focuses of research protocols were challenges and barriers for super capacitor technology. The time duration of search in our search engine was starting from 2017 and end till now. The electric, four-wheeler, hybrid electric vehicles and electric two-wheeler constituted the electric vehicles searched in the databases. These Evs and combination of the resisting and driving forces for super capacitor technology constituted the main search protocol elements in the databases (Vukajlovic et al., 2020).

RESULTS

In this section we look at some of the major obstacles for introduction Evs with super capacitor technology in Pakistan. Introducing high technology based Evs in Pakistan where existing model of vehicle is not compatible with other countries like the current model of Toyota is 10 in Pakistan but in other country it is 11. So how much it is hard to introduce such latest technology Evs. But no doubt the Evs with super capacitor based energy storage system will be the urgent need for every country even. So for the Evs based on super capacitor technology is summarized as:

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Lack of Initiative Policy by Government

Every country economy is purely depending upon their government policy for product and service. Each new product can be easily introduced in market when the government is willing to adopt it. The involvement of government is must to introduce such as mass project in Pakistan. In Pakistan there was a massive adoption of CNG-based vehicles and now there are almost 3.1 million registered CNG vehicles out of 6.1 million vehicles (Cao et al., 2020). It shows that people positively react to the government's awareness scheme with cheap transportation alternatives. Currently, there are no robust plans to implement EVs in Pakistan. Currently the 2016-2020 policy is implemented, so the super capacitor based Evs is currently looking impossible to initiate ("Electric Vehicles in Pakistan : Policy Recommendations Volume I Cars," n.d.).

Need of High Cost for Infrastructure Developed for Charging Stations

The resisting force for any new technology is the cost for infrastructure development. The cost to change or reshape the CNG and petroleum stations into recharging stations for electrically charging super capacitor in Evs is not really easy task. Considering economic condition of Pakistan, the government will be hesitant to invest in infrastructure for E4Ws, as it would benefit the rich only (Massiani, 2015). But there are still chances for E2ws like Electric Rickshaw and electric bikes that is already present in market that some improvement would be possible like high power batteries. But till there is not permanent solution for storage of electricity requirement for E2ws (Kamel et al., 2021).

High Price of super-capacitor Evs

The price is the dominate factor behind avoiding super capacitor Evs. The price of Super capacitor Evs significantly high then gasoline based vehicle. The purchase price of electric cars and hybrids is very high for middle-income people in developing countries. For the lower-income people, the option of medium sized electric scooter or E2Ws can be attractive as sticker price is affordable than a gasoline based car. Already the price is high of gasoline based vehicles, so when the high price super capacitor Evs will introduce, there will be very less demand generate because the majority of population is medium or lower income population (Asghar et al., 2021).

Lack of Awareness

People are not serious about the harmful impact of using emission based vehicle. There is lack of strategy and awareness about the environmental impact. Lack of information or partial information on the available option also leads to the disproval of emerging technology (Li et al., 2017). Only few people are aware about super capacitor energy storing technology. Government's intention to raise awareness through advertising and financial incentives also lures the public to purchase EVs. Nongovernment agencies such as prospective investors would also have to create advertising strategies for their upcoming product (Ahmad & Ullah 2020).

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Stronger customer-base for Gasoline Vehicles

The customer base of gasoline vehicle is very strong. Because there are wide variety of prices from lower to high. In Pakistan in 2016, motorized-two wheeler registration was 70% of total vehicles, indicating that more than half of the traffic mix consisted of two-wheelers. So considering it in mind if Super capacitor Evs are introduced there is open challenge given by the gasoline based existing market of cars, motorcycle and rickshaws due to its low purchase price and high mileage (Yaqoob et al., 2021). Day by day the demand of Gasoline vehicle is increasing because there is only type of vehicle present in Pakistan, because there is 1 out of 10 car or motorcycle is Hybrid Evs (Kouchachvili et al., 2018b).

Limited range of Super capacitor Electric Vehicles

The limited range of super capacitor is also a challenge for under developing countries. In Pakistan there is variety of customer preferences. Our transportation industry is far back than the other country even there is Evs manufacturing started in India. But still our vehicle models are not matched with models that is running all over the world (Tragianni et al., 2017). In developed countries only2 seater or 4 seater super capacitor Evs is introduced because there is more demand for such sport vehicle. But in Pakistan people buy cars that is 5 seaters, so the limited range of seating capacity making super capacitor Evs less favorable for Customer of Pakistan. also the low speed range of super capacitor Evs is one of the main obstacles for the mass adoption of E2Ws as well. The range of a gasoline-based two-wheeler on average is 80–200 km. Whereas, the E2Ws are usually equipped with a lead-acid battery and offer a driving range between 30 and 70 km (Khan et al., 2019).

Shortage of Electricity and High Charging Time of Super Capacitor Evs

It is one of the major barriers place in the adoption of this technology. The current installed capacity for electricity production is 23321 MW. Currently, Pakistan is facing an enormous energy crisis that has created the electricity generation gap of over 5000 MW (Asghar et al., 2021). Long charging time is one of the crucial aspects which influence people to consider EVs as an inferior product. Considering E4Ws, 100% charging requires 3-8 hours of charging with 1.4 kW maximum powers of hybrid electric vehicles. There are frequent blackouts due to power crisis. In Pakistan the load shedding is one of the major problem especially in small cities and villages (Rajper & Albrecht 2020). The production of electricity is much less than the demand. The existing demand is not fulfilling then how the new demand for charging the Evs is a big question that resists this technology need. The major reason for the blackouts in Pakistan is the lack of effective policy making to foresee the rising power demand and the lack of maintenance for the current assets (Horn et al., 2019). The storage of electricity can be hard to maintain especially for E2Ws and E4Ws adoption in Pakistan. The idea of E2Ws and E4Ws reliability to reach the desired destination remains questionable since the blackouts have no particular timetable (Rajper & Albrecht, 2020).

CONCLUSION

The super capacitor based energy storage system is one of the important technologies that could change the world of harmful emission. Super capacitor based Evs is not dream countries

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like America, china and Even India taking initiative toward adopting fuel free vehicle to save environment. The automobile industry of Pakistan is also growing at good rate, but there are major barriers that could be address by the policy makers, government, and general public to take initiative too.

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